STATE GEOLOGICAL SURVEY OF NORTH DAKOTA

FIFTH BIENNIAL REPORT

A. G. LEONARD, Ph. D., State Geologist

BISMARCK
Published for the State Geological Survey
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ADMINISTRATIVE REPORT

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University, N. D., Dec. 1, 1908.

To the President of the Board of Trustees of the University of North Dakota.

SIR: I beg to submit herewith my report on the work of the North Dakota Geological Survey during the years 1907 and 1908.

The publication of the Fourth Biennial Report of the Survey on the clays of the state was delayed somewhat on account of the large number of analyses and tests made on the clays. It was thought that the value of the results obtained would more than compensate for the delay that was necessary in order that they might be incorporated in the report. The volume is the largest yet gotten out by the Survey, containing 340 pages and a large number of illustrations and maps. Among the latter is a colored geological map of North Dakota, showing the distribution of the different rock formations and giving the location of the brick plants. On another map are located the high grade fire and pottery clays of the western part of the state, showing the outcrops and probable extent of the deposits. There has been a widespread demand for this report both from the clay men and others within the state, and also from geologists and other people in all parts of the country. Information regarding the valuable clay resources of North Dakota has thus been widely circulated and cannot fail to be of benefit to the state.

It is the wish of the Survey that its reports be employed as widely as possible in the schools in the teaching of Physical Geography and Elementary Geology. They are already coming into use in a number of the high schools where they are found helpful, especially in the study of local geography and geology. The many illustrations show the topographic features and rock formations, and the reports describe the natural resources of the region. During the past year many hundreds of the reports of the survey were distributed to the larger schools through the co-operation of the County

Superintendents. On his request the volumes were sent to the Superintendent and placed by him in those schools in which they would be of greatest service.

During the summer of 1907, the State Geologist had charge of a United States Geological Survey party of five, having associated with him Mr. Carl D. Smith of the Federal Survey. Detailed work was carried on in the region between Medora and Wibaux, Montana, the area which was covered by the survey being 24 miles wide and lying on either side of the Northern Pacific Railroad. Important discoveries were made regarding the number, extent and distribution of the coal beds, and much information gathered for a report on the region covered. This report is now being published in a bulletin of the United States Geological Survey, and the material which was secured will also be available for, and is being incorporated in, the forthcoming Fifth Biennial Report of the State Survey.

While we were camped near Medora, we were fortunate in having with us for over a week, Dr. A. C. Peale of the Smithsonian Institution, and Dr. F. H. Knowlton of the United States Geological Survey, who were spending the summer collecting fossils at many localities in North Dakota and other western states. These fossils which were collected will make it possible to determine the age of certain formations in the western part of the state, about which there has been some doubt.

Early in August a second party in the employ of the North Dakota Geological Survey, and consisting of the State Geologist and two students of the State University, J. W. Bliss and W. J. Smith, was organized for the purpose of extending the field work beyond the limits of the area covered by the Federal party. The latter party worked west into Montana, and in accordance with an agreement previously made with the United States Geological Survey, I was granted permission to turn the work over to another in order that the investigations might be continued within North Dakota, and additional material thus gathered for the State Survey Report. The party went south from Medora, following the Little Missouri river as far as the southern boundary of Billings county. The coal beds which outcrop in the bluffs bordering the valley and in the badlands on either side, were carefully traced, their thickness and extent noted, and their outcrops located on the map. On Little Beaver creek, in northwestern Bowman county a large collection of fos-

sil shells was made from the Pierre shale, and these were shipped to the University to add to its geological collections. Several weeks previous to this a choice lot of fossil leaves from near Medora had been sent in, along with some very finely preserved fossil fish from the top of Sentinel Butte.

From Little Beaver creek the party traveled northeast to Sand Creek Post Office and White Butte, where the interesting Oligocene formation found in that vicinity was studied and mapped. It was in these beds at the White Butte that the extinct three-toed horse and rhinoceros were discovered several years ago.

Some work was also done during the summer of 1907 in the northeastern part of the state by Mr. V. J. Melsted, who spent six weeks in a detailed study of the cement rock of the Pembina Mountain region. Careful search in the deep ravines and valleys of these mountains, often in the thick and tangled underbrush of that district, resulted in the discovery of many outcrops of the cement beds, which were located on the map. Samples from several localities were collected for analysis and considerable information gathered for a report on the cement materials of North Dakota. During the summer the State Geologist made a trip to the Pembina Mountains where several days were spent in going over some of the ground in company with Mr. Melsted.

During the field season of 1908 the North Dakota Geological Survey carried on work in the eastern and western portions of the state. In the western region the detailed investigations of the coal beds were continued and extended so far to cover those portions of Billings county not already visited or which had not yet been completed. The party, which consisted of the State Geologist, E. H. Wells and H. A. Hanson, traveled northwest from Dickinson, striking the Little Missouri river at the Short Ranch near the mouth of Ash creek, about 25 miles north of Medora. From this point the river was followed down to the mouth of Beaver creek, at the northern boundary of Billings county; then Beaver creek was followed up as far as the Montana line.

A large number of coal beds were found outcropping along the deep valley of the latter stream, and there was much evidence to show that this area is rich in coal. The party now went south through Sentinel Butte to Yule, spending several days in the vicinity of Bullion Butte on the way, and then on to the mouth of Bacon creek, near the town of Marmarth. After completing the

work in the southern part of the county we spent a week in the badlands lying east of the Little Missouri between the mouth of Sand creek and the Northern Pacific Railroad, and another week in the northeastern corner of Billings county.

The material gathered during the past summer, together with that previously secured during several years of field work in the southwestern corner of the state, will be used in the preparation of a detailed report on the geology and coal deposits of that section of North Dakota. This region was selected for detailed study because of the excellent opportunity afforded in the Little Missouri badlands for the examination of the coal beds, where these are so well exposed in numerous outcrops.

A very brief statement of some of the more important results of the field work during the season of 1908 may be given here. It was found that no less than 21 workable coal beds occur in Billings county alone, not all of them occurring at any one point, but some being found in one locality and some in another. These 21 coal beds range from four to thirty-five feet in thickness and are distributed through from 1,000 to 1,200 feet of strata. The aggregate thickness of the coal in these seams is 157½ feet. Some of the individual coal beds cover large areas. One, with a thickness varying from 5 to 16 feet, has a known extent of 20 miles in one direction and 25 miles in another, with an area of at least 500 square miles, and probably much greater. Another seam of coal was traced 36 miles north and south, and 24 miles east and west, and while its known area as shown from outcrops is nearly 900 square miles, it undoubtedly has an extent of 1,000 to 1,500 square miles. This coal bed, with a thickness ranging from 9 to 15 feet and over, has been largely burned out or removed by erosion, but it still underlies a number of townships. At least half a dozen coal beds were discovered which were not before known to occur. The lowest coal seams in the geological column, and therefore the oldest, are those found in the vicinity of Yule, in southern Billings county. The highest and youngest are those which appear in Sentinel Butte and in the northern part of the county.

The discovery of the large fossil bones of the enormous land reptiles known as the dinosaurs was another important result of the summer's field work. These were found in the badlands, a few miles from the town of Marmarth, and several large boxes of them were shipped to the University to add to its collection. Many

of these huge bones were buried in the clays of the region, and some had been washed out and were lying on the surface. This discovery is of increased interest owing to the fact that these fossil bones will make it possible to determine the geological age of the strata in which the fossils occur, the age of the formation having been in doubt up to the present time.

The work in the eastern part of the state was in charge of the Assistant State Geologist, Mr. John C. Barry, a graduate of the Massachusetts Institute of Technology. It consisted in the mapping of the geological formations of Pembina, Cavalier and adjoining portions of Walsh and Ramsey counties, and the investigation of their natural resources. It was found that the northeastern part of North Dakota can be divided, on the basis of its topographic features, into three distinct districts, namely: the Red River Valley; the deeply dissected Pembina Mountains bordering the valley on the west, and the high rolling prairie which forms the greater part of Cavalier county.

The natural resources of the region consist of clay shales suitable for making excellent brick, cement rock, sand and gravel. The more extensive deposits of gravel and sand were located on the map wherever they were exposed at the surface, and in this way the localities where these occur were recorded. Much additional material regarding the cement rock was gathered, and together with that secured the year previous by Mr. V. J. Melsted, will be used as the basis for a report on the cement resources of North Dakota.

Early in September Mr. Barry made a trip to the gas field of Bottineau county for the purpose of investigating the gas wells of that region. Information was secured in regard to the depth, pressure, number and location of wells and other features of the district. The productive area at present appears to be confined largely to the vicinity of the Parker Farm, 9½ miles south of Westhope. The depth below the surface of the gas-bearing sand varies from 160 to 240 feet and it doubtless lies near the base of the glacial drift. This sand layer has a thickness of about 20 feet. Prospecting is now going on with the hope of striking deep-seated and more extensive reservoirs of gas, and one well is down about 1,200 feet. The pressure is reported to be sufficient to blow off at least two million cubic feet per day. Experience in other states show that these comparatively shallow drift wells have not yielded a very

lasting supply, the reservoirs being of no very great extent. But further prospecting at greater depths is warranted by the possibility that deeper reservoirs may exist in the region. Gas is also reported about six miles northwest of Mohall, where several wells have been sunk.

In May of this year, I attended a conference of State Geologists, which convened in Washington, D. C. The gathering was held at the invitation of the Director of the United States Geological Survey, for the purpose of arranging plans of co-operation between the Federal and State Surveys, and to plan the season's work so that there should be as little duplication as possible. The North Dakota Geological Survey has been co-operating with the United States Geological Survey for several years and arrangements were made to continue this along several lines, as in the gathering of statistics of the production of coal, clay products, etc., and in the collection of well records, the Federal Survey bearing all the expense of this work. The conference afforded an opportunity for meeting and discussing with the government geologists various problems encountered in connection with the geology of this region, and was of distinct benefit to the work of the State Geological Survey.

In its work during the next few years the Geological Survey plans to continue the detailed investigations of the coal, clay and cement deposits of the state. These resources are increasing in value and importance with the rapid growth in population, and their proper development will be hastened and assisted by the information supplied by the State Geological Survey in its reports.

In this connection it is interesting to know that a recent estimate by one of the coal experts of the Federal Survey credits North Dakota with having more coal than any other state in the Union, and few people realize what this mineral wealth means to the state.

Another important line of investigation which the Geological Survey has taken up and will devote much attention to during the next few years is the problem of underground water. Well records from all over the state are being collected through the co-operation of well drillers and others, and these will furnish the data from which it will be possible to tell approximately at what depth artesian and other waters may be struck in any part of the region.

The subject of building stone is one which will receive attention and while stone suitable for building purposes is scarce in this

state, those localities where it does occur will be examined for the purpose of determining the extent and quality of the rock.

As in the past years, certain areas such as a county or several counties, will be selected for detailed study, the geology and economic resources will be investigated, the rock formations mapped, and the materials thus secured will be used in the preparation of reports on those districts.

A subject of the greatest practical importance to the people of the state is that of good roads and one of the problems connected with this is where to find the materials for the construction of such roads. It is known that in various localities over our state there are extensive deposits of gravel and sand which are suitable for road metal As soon as the funds are available the State Geological Survey will undertake the investigation of these road materials, including the location and mapping of such deposits, but it cannot be done on the present small appropriation received for the work of the Survey.

It is also exceedingly desirable that the topographic mapping by the United States Geological Survey should be continued and pushed in this state in order that the excellent relief maps of the Federal Survey may include other areas in North Dakota. Many of the states, appreciating the great value of these maps, are appropriating large sums for this work and are thus co-operating with the United States Geological Survey. The latter organization does all the work of preparing the maps and publishes them; all that is asked of the state being that it shall bear half of the expense of the field work only. So far as it is able, the Federal Survey will put in a dollar for every dollar appropriated by the state. For two years the United States Geological Survey has done no topographic mapping in North Dakota, and if any more work of this kind is undertaken in this region the appropriation of the State Geological Survey will need to be largely increased, so that several thousand dollars can be set aside for this purpose. Whether the State Survey can undertake in the near future more than one or two of the lines of investigation outlined above will also depend on whether the present small appropriation is substantially increased.

The North Dakota Geological Survey is acquiring by exchange for its publications an excellent geological library made up of the reports of the Federal and various State Surveys, as well as the reports of a number of similar organizations in foreign countries

The forthcoming Fifth Biennial Report of this Survey will contain the following papers:

"Mineral Production of North Dakota for 1907."

"Natural Gas in North Dakota."

"The Geology of Southwestern North Dakota With Special Reference to the Coal."

"The Geology of Northeastern North Dakota With Special Reference to the Cement Rock."

The report will also contain a chapter treating in a popular way the geology of North Dakota, intended particularly for the use of the schools.

Respectfully submitted,
A. G. LEONARD.
State Geologist.

The Little Missouri badlands in southern Billings county. This view and the one shown in Plate II were taken from the same point, looking in opposite directions. Photo by A. L. Fellows.

GEOLOGY OF SOUTHWESTERN NORTH DAKOTA

WITH SPECIAL REFERENCE TO THE COAL

BY

A. G. LEONARD

THE GEOLOGY OF SOUTHWESTERN NORTH DAKOTA WITH SPECIAL REFERENCE TO THE COAL

BY A. G. LEONARD.

INTRODUCTION

The area treated of in this report occupies the extreme southwestern portion of North Dakota and includes the counties of Billings and Bowman. It is therefore bordered on the south by South Dakota, on the west by Montana, on the north by McKenzie county, while on its eastern border lie Dunn, Stark, Hettinger and Adams counties. The district has a length from north to south of 96 miles and a width varying from 38½ to 53½ miles, with a total area of about 4,567 square miles. Billings county alone comprises 3,400 square miles, being almost three times as large as Rhode Island, and Bowman county has an area of 1,167 square miles.

The region under discussion affords an exceptionally fine opportunity for the study of the coal beds, since there are abundant outcrops along the Little Missouri and its numerous tributaries, particularly in Billings county. The river traverses the area from south to north and has cut a deep valley along the sides of which the rock formations are excellently shown. Then, again, in no other portion of the state is there such a variety of geological formations and for this reason the district is of unusual interest. The famous and picturesque badlands of the Little Missouri, which do not extend far south of Billings county, occupy nearly one-third of the area, or some 1,400 square miles.

Until within the last few years the region has been given almost wholly to stock raising and has afforded a splendid range for vast numbers of cattle and horses, but recently the farmer has taken possession of much of the prairie land and is gradually crowding out and displacing the ranchman.

Geological investigations of a general character have been carried on in this region by a number of geologists. Among the first

to visit it was Charles A. White, who as early as the summer of 1882 examined the beds on top of Sentinel Butte and discovered in them two species of fossil fishes.[1] During September, 1883, Professor E. D. Cope spent some time collecting vertebrate fossils in what was probably southeastern Billings county, and he refers to the discovery of White River strata in that area.[2] In the summer of 1902, F. A. Wilder spent three weeks in the same county studying the coal beds,[3] and the following season L. H. Wood went down the Little Missouri in a boat from Medora and continued the investigation of the coal deposits along that stream.[4] In 1905 Earl Douglass of the Carnegie Museum at Pittsburg visited White Butte in southeastern Billings county and collected there many fossil mammals.[5] The writer began work in the region in 1904, spending several weeks there during that year. In 1905 he had charge of a United State Geological Survey party which spent some time in southern Billings and Bowman counties, but not until 1907 were detailed investigations undertaken. In that year a United State Geological Survey party under the joint direction of A. G. Leonard and Carl D. Smith began work at Medora and carried it westward into Montana, covering an area 24 miles wide extending north and south of the Northern Pacific railroad. In the field work they were assisted by Fred H. Kay and W. H. Clark. The detailed study of the beds resulted in the collection of new data regarding the region which is briefly set forth in a recent bulletin of the United State Geological Survey.[6] Again in 1908 the writer with a party spent several months in the field, extending the investigations to those portions of the area in which the work was not completed.

PHYSIOGRAPHY

DRAINAGE.

The drainage of the southwestern corner of the state is well developed and there is scarcely a township which is not traversed by several streams whose branches reach out to all parts of the surface. There are in this area nearly forty streams which have a greater length than ten or fifteen miles and the majority of them are much

[1] Amer. Jour. Sci., Third Series, Vol. XXV, pp. 411-416.
[2] Proc. Amer. Philos. Soc., 1883, Vol. XXI, pp. 216-217.
[3] Second Biennial Rep. N. D. Geol. Surv., pp. 63-74.
[4] Third Biennial Rep. N. D. Geol. Surv., pp. 41-125.
[5] Annals of the Carnegie Museum, Vol. IV, Nos. III and IV, 1908, pp. 265-271.
[6] Bull. U. S. Geol. Survey No. 341, 1908, pp. 13-33.

longer than this. The Little Missouri river drains nearly two-thirds of the district and entering it near the extreme southwestern corner flows north across its entire length. Beaver creek, a tributary of the Little Missouri, and which joins the latter stream close to the northern boundary, includes in its drainage basin ten of the northwestern townships, while there is one township in the extreme northwest corner which drains into the Yellowstone river.

The rivers which flow east into the Missouri, the Knife, the Heart, the Cannon Ball and the North Fork of the Grand all have their sources in Billings and Bowman counties and drain a strip of territory along the eastern border.

The Little Missouri river, after traversing the southern half of the district, changes its direction and flows nearly due east for twelve miles; then again making an abrupt turn it flows northwest past Bullion Butte and continues in a northerly direction. South of Bullion Butte and near the point where the river changes its course from east to northwest, two large streams enter it from the south, namely, Deep and Sand creeks. The former has its source thirty miles distant in Bowman county, and the latter in White or Chalk Butte, and they empty into the Little Missouri less than a mile apart, their combined drainage basins comprising about 400 square miles.

Naming them in order from south to north, the following important creeks enter the river from the east, above the mouth of Deep creek: Coyote, Bacon, Indian, Cash and Spring creeks. From the west the tributaries are Big Box Elder, Little Beaver, Cannon Ball, Horse, Bull Run and Williams creeks.

Between the mouth of Sand creek and Medora, the large creeks entering the Little Missouri on the east are Third, Bear, Dance, Davis and Sully, while on the west they are Bullion, Garner and Andrews creeks, the last three named being the most important and varying in length from 20 to 25 miles. Andrews creek is followed by the Northern Pacific railroad between Medora and Sentinel Butte.

Between the railroad and the northern limits of the area the major tributaries from the east are Paddock, Government, Franks, Ash, Blacktail, Whitetail and Magpie creeks; from the west they are Knutson, Wannigan and Roosevelt creeks.

By means of these many large tributaries and numerous smaller ones the Little Missouri drains nearly two-thirds of the district.

The North Fork of the Grand river flows for thirty miles near the southern border of Bowman county and with its three tributaries, Spring, Lightning and Buffalo creeks, drains over fifteen townships.

The North Fork and South Fork of the Cannon Ball river, which flows east into the Missouri, have a drainage area of over 440 square miles, their source being in the White or Chalk Butte, in southeastern Billings county. The headwaters of the Heart river also lie within the district under discussion, although they only drain a narrow strip of country along the eastern border. Farther north something over four townships drain into the Green river, a branch of the Heart, while in the extreme northeast corner the Knife river takes its rise.

The northwestern part of the area is crossed by Beaver creek, which enters from Montana and joins the Little Missouri close to the northern boundary. Elk creek is its chief tributary and together these two streams have a drainage basin within the district of about nine townships. The extreme northwestern corner, including some forty square miles, drains northwest into the Yellowstone river.

By far the greater number of streams in the area are intermittent and are dry during a considerable portion of the year, or their channels are occupied only by scattered pools of water. During and for several days following a rain the valleys are occupied by large creeks or, in case of a hard storm, by raging torrents. Then after the water has drained away the streams cease to flow and dry up wholly or in large part. Some of the larger creeks continue to flow throughout the year, as Beaver, Little Beaver, Sand and Deep creeks, while a few of the smaller, which are fed by good sized springs, as Ash creek, likewise have a constant flow.

The divide separating the drainage of the Missouri from that of the Little Missouri lies only 10 to 15 miles from the latter stream, but is from 100 to 120 miles west of Missouri river. It has an abrupt slope on the west and a gradual slope on the east. This is well shown at the head of Sully creek, eight or nine miles east of Medora, where a line of bluffs 200 feet high forms the western slope and on the opposite side the surface has a gentle inclination toward the east. The difference in the character of the country on the opposite sides of the divide is even more strikingly shown at the headwaters of Green river and Ash creek. The former stream has a broad, shallow valley, with a relatively slight fall; the surface is

The level, treeless plain. This picture and Plate I show the contrast between the upland plain and the badlands, and that they were taken from the same point indicates the abruptness of the change. Photo by A. L. Fellows.

rolling and occupied by farms. Ash creek, on the other hand, has a very narrow and steep-sided valley at its source, with deep and vertical-walled gullies in the bottom of it. The descent from the top of the divide is over 250 feet in a little over one mile and the creek has a steep gradient all the way to the river.

The streams on the west side of the divide, with their rapid fall and swift current, are eroding faster than those on the opposite slope and as a result the divide is being slowly shifted toward the east and away from the Little Missouri. The tributaries of the latter river are lengthening and reaching out into new territory, and are slowly encroaching on the headwaters of the Green river. The divide will continue to migrate eastward until the opposite slopes are more nearly equal and the rate of erosion is the same on both.

TOPOGRAPHY.

Four topographic types are represented in this region, namely, uplands, lowlands along the stream valleys, badlands, and river terraces. The upland areas comprise something more than one-half of the region and their surface is a more or less rolling plain. This is most extensive in the southern half of the district, although in the northern townships it occupies large tracts.

This upland plain or plateau is the result of long-continued erosion and doubtless represents a peneplain which has been produced since Oligocene time. Its elevation varies from 2,700 to nearly 3,200 feet above sea level. In this plain the streams and their countless tributaries have cut their channels and the region is very thoroughly drained. Everywhere the surface is made up of slopes leading to some drainage course. As one rides day after day over this treeless prairie, which stretches away in all directions as far as the eye can reach, its vastness and boundless extent make a lasting impression on the mind.

A conspicuous feature of this region is the high buttes which rise from 400 to 650 feet above the plain and form prominent landmarks which may be seen from afar. In Billings county there are at least eight buttes which are worthy of mention by reason of their size, namely, Sentinel, Camels Hump, Square or Flat Top, Bullion, Black, Chalk or White, East Rainy and West Rainy. With the exception of Camels Hump and White buttes, these are all flat topped and capped by a massive sandstone layer, which has given them their level summits. They are formed of nearly horizontal beds of sand

and clay which were once continuous over the entire region but have now been largely removed by erosion, leaving these remnants to show the former extent and thickness of the strata. The buttes are favorably located with reference to drainage and while the streams and rains have washed away hundreds of feet of material from this entire district, these outliers have been left, although they are themselves slowly wasting away under the ceaseless action of running water. The thickness of the beds thus removed from extensive areas in this part of the state can not have been much less than 1,000 feet, and it may have been more.

Sentinel Butte, which so far as known is the highest point in the state, has an elevation of 3,300 feet above sea level and rises 650 feet above the station of the same name, located on the plain below. On top of the butte are the remnants of a still higher formation which has been almost wholly removed, but which was doubtless several hundred feet thick. A number of the tributaries of the Little Missouri have their source close to the base of Sentinel Butte, and the latter is located on the divide between Beaver creek and the Little Missouri.

About five miles north of Sentinel Butte is Camels Hump, and Flat Top or Square Butte lies about the same distance to the east. Unlike most of the high buttes of the region Camels Hump has a rounded summit.

Bullion Butte, which is located within the great bend made by the Little Missouri, about fifteen miles south of Medora, is the largest butte in the region. It has an elevation of 950 feet above the river and from its summit all of the high buttes of the area can be clearly seen, together with others which are more distant. East Rainy and West Rainey Buttes are in the southeastern corner of Billings county, only a few miles from the border. Black Butte lies eight miles north of the southern boundary of the county and in it several tributaries of Sand and Deep creeks have their source. White Butte, so named from the chalky whiteness of the calcareous sands and clays forming it, is located five miles east of Black. It does not have the flat top common to all the other high buttes except Camels Hump, and it is not capped with the massive sandstone found on them.

These ledges of sandstone capping the high buttes and varying in thickness from fifty to a hundred feet, form vertical cliffs just be-

low their summits, and below these are the more gradual slopes produced by the weathering of the sandstone and shales. At the base of the sandstone cliffs are huge masses of rock which have broken off from the ledges above and accumulated in great talus piles. In northern Bowman county are the Twin Buttes, which form conspicuous landmarks visible from a great distance in every direction.

In addition to the larger buttes mentioned above there are great numbers of low buttes which are commonly capped with red burnt clay formed by the burning of lignite beds. This burnt clay or clinker has determined the height of these smaller buttes and protected them from erosion. They are well shown in the vicinity of Sentinel Butte, where they rise from 150 to 175 feet above the surrounding surface. Their uniform height is the result of the burning of the twenty-one-foot coal bed which is present in Sentinel Butte and the formation of the thick layer of clinker which occurs on the top of each.

The most prominent topographic feature of the entire region is the valley of the Little Missouri river, which, as already stated, traverses the entire area from south to north. The character of the valley varies so widely in different parts of its course that a description of one portion would not apply to another, and it will be necessary therefore to discuss separately the valley as it appears in Bowman and Billings counties. In the former county the bluffs rise only about eighty feet above the river. At this elevation there are broad flats which stretch away from the river and merge gradually into the upland plain. This plain back several miles from the stream reaches an elevation of 200 to 250 feet above the Little Missouri. Throughout its course in Bowman county the sides of the valley are covered with vegetation for the most part and the only outcrops are at points where the river swings against the bluff.

The valley as it appears in Billings county presents a strong contrast to the foregoing. The river has here cut its gorge to a depth below the upland plain of from 420 to 440 feet and with a width at the bottom of from one-half to one mile. The valley consists of an inner narrow portion and an outer wide portion. The inner valley is bordered by bluffs which rise very abruptly from the river to a height, in the vicinity of Medora, of 240 feet. At this elevation broad flats or terraces occur on either side of the Little Missouri. They have a width of from one to two or three miles and overlooking them are bluffs rising quite abruptly 160 to 200 feet above the

flats, or about 420 feet above the river. These wide flats were probably formed when the land was considerably lower than at present and the river, having reached base level, meandered back and forth over a flood plain several miles in width. The surface was then elevated, the river gained new erosive power and has since cut its inner gorge to a depth of some 240 feet below the old valley bottom, represented by the flats.

These wide flats are especially well developed at the following points along the Little Missouri, beginning at the south and going down the river. On the west side of the valley for several miles below Little Beaver creek, where the flat has an elevation of 110 feet above the river; in the vicinity of Yule, particularly on the west side of the valley and below the mouth of Williams creek, the elevation being 200 feet; within the large loop made by the river where it swings around to the east, just above the mouth of Spring creek, and on the north side of the valley throughout its eastward course, the elevation here being 210 feet; east of Bullion Butte, between it and the river, where the flat covers six to eight square miles and lies 230 feet above the river (Plate IV., Fig. 1); just north of here on the east side of the river, between Bear and Dance creeks, the flat having an elevation of 230 feet; just below Medora, and five miles below that town, between Knutson and Wannigan creeks, where the flats have an elevation of 240 feet; on the east side of the valley about two miles below mouth of Roosevelt creek, and several miles below this locality, across the river from Mikkelson Post Office, the high flats in this portion of the Little Missouri having an elevation of 280 feet above the river. (Plate III., Fig. 1.)

In some places there is not one, but two, three or even more of these high terraces, though generally there is one which is much more extensive and better developed than those above or below, and it is the elevation of this main flat that is given in the preceding paragraph, in case there was more than one at any given point.

The trench-like inner valley, which has been cut below the level of these broad terraces, has a nearly level bottom from which rise the almost vertical bluffs. These bare bluffs, with their horizontal banding produced by the alternating beds of variously colored sandstones and shales, rise with great abruptness from the flood plain of the river to a height of 200 to 300 feet and over. They do not merge gradually into the upper plain, but the same steep slopes continue clear to the top of the bluffs, so that they make a sharp angle

Fig. 1. The high flat or terrace bordering the valley of the Little Missouri near Mikkelson.

Fig. 2. The valley of the Little Missouri, showing the extensive low flat or terrace forming the valley bottom at the mouth of Blacktail creek.

with the upland surface. These nearly vertical walls line either side of the valley almost continuously except where they are broken by a tributary valley entering the main one.

Low terraces also border the river throughout its course, the upper one having an elevation of about twenty feet above the average stage of the water in the Little Missouri. In many places along the stream these terraces form extensive low flats which were once the flood plain of the Little Missouri, but are now high enough to escape overflow except in unusually high water. Among the largest of these lower flats are those occurring on either side of the river near the mouth of Blacktail and Whitetail creeks, the area occupied by these being not far from 1,200 acres. Other good sized flats are found at many points along the course of the valley. (Plate III., Fig. 2.)

A very marked characteristic of the Little Missouri river is its meanders. It curves and winds back and forth across its valley, forming numerous great loops and causing its course through the county to be much longer than it would otherwise be. Measuring all the bends the length of the river in Billings and Bowman counties is approximately 175 miles, while if its channel were straight it would not be over 125 miles. In other words, the length of its valley is 125 miles, while the length of the crooked channel is 175 miles. Since the stream in its meanderings strikes first one and then the opposite bluff, it cuts the valley bottom into disconnected flats and the road following the valley crosses the river again and again, along several stretches it being necessary to ford the river twenty times in going as many miles. The meanders are particularly well developed in the vicinity of Yule and between that place and the southern boundary of Billings county, though they are by no means confined to this part of the valley. South of Bullion Butte, and on the south side of the river, in sections 3, 10 and 11 of T. 136, R. 103, there was formerly a large oxbow loop, but the river has cut across the narrow neck of land within the bend and taken the shorter course, abandoning its old channel, which is now largely filled with sediment.

The fall of the Little Missouri river between Medora and its junction with the Missouri is 520 feet, or an average fall of 3½ feet per mile. Above Medora the fall is considerably greater, the stream descending 460 feet in the 70 miles between the Chicago, Milwaukee

& St. Paul railroad crossing at Marmarth, near the southern boundary of Billings county, and Medora, or an average fall of 6½ feet per mile.

The Badlands.—Bordering the Little Missouri on either side and occupying almost one-third of the entire area, or approximately 1,400 square miles, are the famous badlands. They are not confined entirely to that stream, but are also found along Beaver creek, Deep creek, the Knife river and other streams. This tract of rough country along the Little Missouri has its greatest width near the northern border of the district under discussion, where Beaver, Blacktail, Whitetail and Magpie creeks with their many tributaries have eroded a labyrinth of deep gorges and ravines covering a strip twenty-five miles wide. South of here for a distance of forty miles, or as far as the mouth of Sand creek, the badlands are from fifteen to twenty miles in width. From this point to the southern boundary of Billings county they are not more than half as wide, while in Bowman county they are neither so well developed nor so extensive as farther north.

A word of explanation concerning the use of the term "badlands" may be added here. The land is not bad in the sense commonly understood by that word, for the soil is for the most part very productive when supplied with sufficient moisture. But the badlands are so extremely rough that they are very difficult to travel through and are in places impassible. They are bad in the sense probably meant by the old French term *mauvaises terre,* originally applied to the region with reference to its being a land bad for the traveler.

The badlands have been produced mainly by stream erosion and rain erosion acting on the soft clays and sands of the region. Through the agency of running water the nearly horizontal strata have been carved and sculptured into the infinite variety of weird and fantastic forms so characteristic of badland scenery. The erosion is greatly facilitated by the sparseness of the vegetation, the steeper slopes being almost bare of verdure. Though the region is one in which the rainfall is comparatively light, every shower is highly effective in washing away the unconsolidated clays and sands. Every slope, the sides of every butte and hill, bear the marks of the last shower. They are grooved with countless tiny channels formed by the rills and rivulets of water which poured down the slopes. Many creeks enter the river and each of them has its tributaries which are branching out and pushing back farther and farther. These

streams have cut their way deeply into the beds of clay and sand, thoroughly and minutely dissecting the region into a network of canyons, gorges, ravines and gullies. The badlands extend back from the river to the headwaters of the creeks tributary to it, and the latter are in most cases so near together that the rough country along one stream merges into that along the next stream, making a nearly continuous strip of badlands along either side of the Little Missouri.

In some places the change is abrupt from the upland plain to the badlands. There are commanding points on the edge of the latter where the view in opposite directions presents a most striking contrast. On the one side the eye looks out upon an indescribable waste, a chaos of bare ridges, bluffs, buttes, mesas, domes, pinnacles and countless strange forms carved from the soft strata of the region. (Plate I.) The scene has a strangeness and fascination so that one turns from it with reluctance and the eye never tires of returning to it. How different is the view presented in the opposite direction where a flat, featureless plain stretches away to the horizon, with not even a tree to break its monotony. The streams, if any are present, have cut only shallow valleys in the plain and the few slopes are gentle and grass covered. (Plate II.)

The greater part of the rain which falls upon the surface runs off at once into the streams, causing them to rise rapidly and become muddy torrents. Channels which have long been dry are filled by swiftly moving floods which sweep away vast quantities of sediment and rapidly erode the soft strata of the region.

One of the effects of these rivulets of water which flow during and shortly after a shower is the excavation of great gulches or trenches in the bottom of the valleys. These often have a depth of twenty to thirty feet, with vertical sides and flat bottom and they terminate abruptly at their upper end in an overhanging bank over which the torrent falls, rapidly undermining and cutting back the head of the gulch. These vertical-walled and deep gulches or miniature canyons sunk in the bottom of the valleys are very characteristic of the badlands and render travel through them so difficult.

One of the most notable features of the badlands is the bare clay slopes in which the variously tinted strata appear as horizontal bands running along the faces of the bluffs and buttes. The prevailing colors are shades of gray, yellow, brown, black and red. But while

many of the slopes are bare, the surface of the region as a whole is clothed with vegetation and furnishes excellent pasturage for stock.

While stream erosion and rain erosion acting on the horizontal beds of unconsolidated clay and sand are the chief factors in the formation of the badlands, the burning out of the beds of lignite has been of great importance in giving them their present aspect. The burning of the coal has been going on for thousands of years and is still in progress in many places. Coal beds from ten to fifteen feet thick and covering hundreds of square miles are now largely burned out and there are few extensive tracts in the badlands where the effects of the heat thus produced are absent. The overlying clays and sands are burned and changed to a red color and often they are completely fused to a slag-like mass. (Plate XI., Fig. 1.) This clinker, or "scoria" as it is locally called, is much harder and more resistant than the shales and sandstones of the region and often caps the buttes, ridges and bluffs, protecting them from erosion. The beds of clinker vary in thickness from a few feet to forty, fifty and even a hundred feet, and with their bright red colors are conspicuous features of badland scenery. In some localities, as in the vicinity of Flat Top and Sentinel buttes, huge masses of fused clay cover the slopes and form the capping layer of every butte. A thick bed of burnt clay forms the topmost layer of the higher bluffs and ridges along the Little Missouri from Medora to Bullion Butte, and the same clinker bed is found along Andrews creek and Sully creek, composing the masses seen from the railroad. The effects of the burning out of the lignite beds are well shown where the fires are still burning. The overlying clays settle down and form a depression nearly as deep as the thickness of the original bed of coal, at the same time wide cracks are opened in the earth and the materials above the coal are thus much broken and fractured. In this way a supply of air reaches the burning lignite and it smoulders slowly on, working its way back farther and farther as the surface settles and new fissures are opened over the burning bed. At the same time the clays are hardened and frequently fused, their color changing to red or pink. (Plate XI., Fig. 2.)

The effects of this destruction of the lignite beds are not confined to the badlands, and there are some extensive districts where the topography is very largely the result of this process. Thus, in the drainage area of Deep creek, west and southwest of Black Butte, the surface has a peculiar hummocky character when seen from the

Fig. 1. The Little Missouri valley at the mouth of Deep creek. In the background at the right the broad upper terrace between Bullion Butte and the river is well shown.

Fig. 2. Grass-covered slopes and scattered pines near the mouth of Sand creek, in the North Dakota Forest Reserve.

top of this butte, being thickly dotted with rounded knolls or hummocks. These are fifty to sixty feet and over in height and most of them are covered by and composed largely of masses of clinker. They have clearly been formed by the burning of a thick bed of coal, as a result of which the ground settled unevenly and much of the surface materials have been swept away by Deep creek and its tributaries, leaving the harder or more resistant portions behind to form the hundreds of rounded knobs with their covering of red burnt clay.

Elevations.—So far as known, the highest point in North Dakota is found in Billings county. The top of Sentinel Butte has an elevation of 3,350 feet above sea level, or 650 feet above the station of the same name. Bullion Butte, about eighteen miles southeast of Sentinel, rises 925 feet above the Little Missouri at the mouth of Bullion creek, or between 3,250 and 3,300 feet above sea level. But aside from these high buttes which rise hundreds of feet above the surrounding country, the surface of the upland plain itself, which occupies the greater part of the area, reaches a high elevation in certain districts. It probably attains its greatest height in northwestern Bowman country, on the divide between Deep creek and Spring creek, the latter a tributary of the North Fork of the Grand river, and the Little Missouri. There is a large area here which is over 3,000 feet above sea level and the station of Rhame on the Chicago, Milwaukee & St. Paul railroad has an elevation of 3,189 feet.

Tracts of country occur on the west side of the Little Missouri, on the divide between that stream and Beaver creek in Montana, with elevations of 2,800 feet; and one or two miles west of Fryburg, on the edge of the badlands, the divide is 2,800 feet above sea level. Another high area is in northeastern Billings county, on the divide between the Green and Little Missouri rivers. The lowest point in the region under discussion is in the valley of the Little Missouri at the mouth of Beaver creek, the elevation here being approximately 2,070 feet above sea level. This gives a difference of elevation between the lowest and highest points of nearly 1,300 feet.

The bottom of the valley of the Little Missouri at Marmarth in southern Billings county, is 2,717 feet above sea level, or higher than the town of Sentinel Butte, located on the upland plain forty miles north.

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Nautilus dekayi Morton.
Aporrhais biangulata M. & H.
Inoceramus cripsi var. *barabini* Morton.
Cuspidaria moreauensis M. & H.
Lucina occidentalis Morton.
Avicula linguiformis E. & S.
Callista deweyi M. & H.
Chlamys nebrascensis M. & H.
Leda (Yoldia) evansi M. & H.
Lucina occidentalis var *ventricosa* M. & H.
Scaphites nodosus (Owen).
Dentalium gracile M. & H.
Anisomyon sp.
Pyrifusus newberryi M. & H.
Ostrea pellucida M. & H.
Nucula cancellata M. & H.
Protocardia subquadrata E. & S.
Lunatia sp.
Dentalium sp.
Anisomyon patelliformis M. & H.
Haminea occidentalis M. & H.
Fasciolaria (Cryptorhytis) flexicostata M. & H.
Baculites ovatus Say.
Cuspidaria ventricosa M. & H.?
Scaphites nodosus Owen var. *brevis* and *plenus*.

FOX HILLS FORMATION.

The upper member of the Montana group and the most recent of the marine Cretaceous strata is the Fox Hills formation, which overlies the Pierre and occupies a strip of country surrounding its outcrop, as shown on the map. The beds are somewhat lighter than those beneath, and when weathered are buff colored. They are well shown in outcrops on Little Beaver creek opposite the mouth of Corral creek and near the line between sections 7 and 18, T. 132, R. 106. At the base of the section exposed at this point, and not far above the base of the formation, there are about 25 feet of very

absence of the jointing so well developed in the underlying Pierre shale. The fossil-bearing calcareous concretions are also wanting in these beds. Above the laminated clays occurs a ledge of yellow sandstone eight to ten feet thick and overlying the latter are fifty feet of light greenish gray sandstone. A section of these beds resting on the Pierre and exposed on Little Beaver creek is therefore as follows:

	Feet.
Sandstone, light greenish gray, massive	50
Sandstone ledge, yellow	8–10
Clay, sandy, finely laminated	20–25

At the top of this formation is an unconformity separating it from the overlying strata. The sandstone has here been eroded and its upper surface is undulating, while resting on it is a brown to black, very carbonaceous and clayey sandstone. This unconformity appears at two points along Little Beaver creek, one near the southern edge of section 7, T. 132, R. 106, and the other near the centre of the same section. (Plate V.)

No fossils were found in these beds lying between the Pierre shale and the unconformity and their reference to the Fox Hills formation is only provisional and is based partly on their stratigraphic position, which is similar to that of the Fox Hills sandstone in the Hell Creek region of eastern Montana, and partly on their resemblance to the beds of that region. They differ from the Pierre shale on which they rest in color, in consisting largely of sand, in their lamination, and absence of jointing. They are separated from the overlying strata by an unconformity. These beds thus appear to comprise a rather distinct division and for the reasons stated above they are provisionally referred to the Fox Hills formation.

TERTIARY.

LOWER FORT UNION OR DINOSAUR-BEARING BEDS.

For many years all the beds above the marine Cretaceous rocks were regarded as belonging to a formation which has been called by some the "Laramie," by others the "Fort Union." The work of the past few years in eastern Montana and western North Dakota has shown, however, that the Laramie probably does not occur at all in the region and that the beds above the marine Cretaceous belong to the Fort Union formation.

Fig. 1. The unconformity at the base of the Fort Union, on Little Beaver creek, Bowman county.

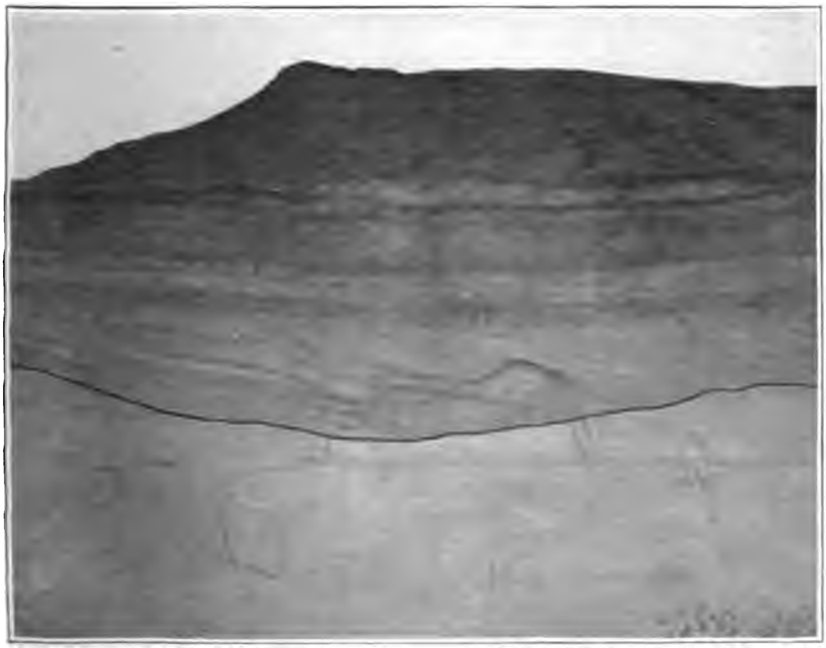

Fig. 2. The same unconformity as that shown in Fig. 1, as it appears at another point half a mile distant, also on Little Beaver creek.

Fig. 1. Bluff of the Little Missouri river at the mouth of Bacon creek, showing the dinosaur-bearing beds of the lower Fort Union.

Fig. 2. The Tepee Butte bluff of the Little Missouri, near the mouth of Deep creek, 584 feet high. The contact between the light colored middle member and the dark colored upper member of the Fort Union is well shown toward the top of the bluff.

The Fort Union rocks are readily separated into three members by a marked difference in character and appearance. The entire thickness of all three divisions is well shown in the area under discussion, which is especially favorable for the study of the various members of this formation. The upper beds are composed of rather dark gray sandstone and shale, with many brown, ferruginous, sandy nodules and concretions. The middle member is formed of light ash gray and buff shales and sandstones, which are remarkably uniform in color and appearance over extensive areas. These two divisions of the formation contain abundant plant remains of modern aspect which leave no doubt that the beds are of Fort Union (early Eocene) age.

The lower member is composed of the dinosaur-bearing somber beds. These likewise contain a flora which Dr. F. H. Knowlton, of the United States Geological Survey, regards as "beyond all question a Fort Union flora."[1] The basal portion of these somber beds contains large numbers of dinosaur bones and occupies the same relative position to the formations above and below as the "Hell Creek Beds" described by Mr. Barnum Brown.[2]

Associated with the dinosaur bones in the lower portion of the somber beds plants are also found which Dr. Knowlton states are likewise typical Fort Union species. The flora thus furnishes evidence that these dinosaur-bearing beds belong to the Fort Union and they are doubtless to be regarded as forming a part of that formation.

The somber beds cover a considerable area in southwestern Billings and western Bowman counties. They are well exposed in the bluffs of the Little Missouri valley for twenty miles above and below the point where the Chicago, Milwaukee & St. Paul railroad crosses that river. (Plate VI., Fig. 1.) Farther west in Montana these beds occur along the Yellowstone between Glendive and Miles City, and are well shown north of Miles City, in the Hell Creek region. In many places they are seen to be overlain by the light gray and buff middle member of the Fort Union. At Signal Butte near Miles City, for example, the somber beds rise 500 feet above the Yellowstone river, while resting on them and forming the upper part of the butte are 200 feet of buff beds belonging to the middle member. On the Little Missouri river below Yule the same contact between the lower and middle divisions of the Fort Union is seen.

[1] In letter to the writer.
[2] Bull. Am. Mus. of Nat. Hist., Vol. XXIII, pp. 823-845, 1907.

The dinosaur-bearing beds as a whole have certain distinctive features by which they may be readily recognized. They are composed mainly of alternating layers of shale and soft sandstone, and have a notably dark and somber aspect in marked contrast to the buff and light gray of the overlying member of the Fort Union. The prevailing colors are dark gray, together with many brown bands, but weathered surfaces, especially when moist, frequently have a greenish gray or olive color. Beds of brown, carbonaceous clay shale are very common and conspicuous. These strata also contain much dark brown, ferruginous material, occurring both in thin seams and concretions, the latter being most numerous at certain horizons, and fragments of this cover the slopes in many places. Another characteristic is the great number of sandstone concretions, some small and others eight to ten feet in diameter, and very irregular in shape. (Plate VII., Fig. 1.)

No workable coal is found in the lower 300 feet or more of the somber beds, and in some portions of the area only thin coal seams occur throughout their entire thickness. Thus in the Pretty Butte section there is no coal bed over two feet thick, and in those which are present the coal is impure and mixed with clay. In the 250 feet of strata exposed at the mouth of Bacon creek there is practically no coal, the thickest seam being only fifteen inches, and the same is true for all the somber sandstones and shales exposed along the Little Missouri river from the Pretty Buttes south to the South Dakota line. But while only thin and unworkable coal beds occur in the lower part of this member, in the upper portion thick beds of coal are found in many places. In the vicinity of Yule five or six of these are present in the upper part of the formation, and the coal on Bacon and Coyote creeks is at about the same horizon.

At their base the somber beds are separated from the underlying formation by the unconformity already mentioned on a previous page. At the top they are not everywhere so sharply marked off from the overlying light colored member of the Fort Union, though they may generally be separated by means of their marked difference in lithologic character, including their contrast of color.

The thickness of the somber beds in southwestern North Dakota is approximately 600 feet. In the Hell Creek region of Montana the thickness of these strata, including the "Hell Creek Beds" of Mr. Barnum Brown, is 410 feet and they measure about the same at Glendive.

The character of this lower member of the Fort Union is shown in the following detailed section which was measured in the Pretty Buttes, five miles below Marmarth, on the west side of the Little Missouri river. It illustrates the rapid alternation of materials in this formation.

Pretty Buttes Section.

	Feet.	Inches.
Burnt clay bed, capping the buttes	26	
Clay, gray	2	
Sandstone, fine-grained, buff	8	9
Shale, gray	2	9
Shale, light buff	9	
Shale, chocolate brown, carbonaceous	2	
Coal, impure and dirty		11
Shale, brown		9
Coal, impure		8
Sandstone and shale, chocolate brown, carbonaceous	2	
Sandstone, gray	12	
Shale, gray	2	
Shale, brown, carbonaceous	4	3
Coal, impure		8
Sandstone, fine-grained, gray	15	6
Shale, chocolate brown	1	7
Sandstone and shale, not well exposed	21	5
Shale, brown	1	
Sandstone, gray	11	3
Earth, black, carbonaceous		3
Sandstone, argillaceous, gray	3	7
Shale, gray	5	9
Sandstone, gray	3	9
Shale, gray	10	6
Coal, impure and dirty		11
Shale, chocolate brown	1	2
Sandstone		10
Shale, chocolate brown	1	3
Sandstone, argillaceous	3	7
Shale, brown, carbonaceous, with some coal	1	
Shale, gray	2	
Coal, impure		6
Sandstone, light gray	23	
Coal, impure, with 7-inch clay parting	2	
Shale, chocolate brown, carbonaceous	2	
Shale, sandy, changing in places to sandstone	58	
Coal and brown shale	1	4
Sandstone with some clay, gray	8	9
, carbonaceous	1	4

	Feet.	Inches.
Coal, impure	2	
Shale, brown, carbonaceous		8
Sandstone, gray, with some shale	63	4
Shale, brown, carbonaceous	1	
Shale, gray	1	6
Sandstone, gray	6	
Shale, brown, carbonaceous	2	3
Sandstone	3	
Shale, gray	7	5
Sandstone, gray, with limonitic concretions	16	6
Shale, gray	4	9
Shale, sandy, passing into sandstone above, gray; contains numerous brown, limonitic nodules	22	
Shale, dark brown, carbonaceous, with thin streaks of coal	1	1
Shale, light gray	6	10
Shale, dark gray to brown	2	9
Shale, gray, sandy above	5	2
Shale, brown, carbonaceous	3	4
Clay, greenish gray	2	6
Sandstone, gray, with great numbers of sandstone concretions and lenses	13	4
Shale, brown, carbonaceous	2	9
Clay, greenish gray	3	
Sand, gray	3	9
Shale, brown, carbonaceous, with streaks of coal	4	7
Shale, sandy	5	
Unexposed to river	20	
	460	

All of the strata exposed in the above section belong to the somber beds, with the exception of the upper thirty or forty feet which are thought to belong to the middle member of the Fort Union.

The base of the section is probably nearly 200 feet above the base of the somber beds, since the contact of these with the underlying formation is found not far above river level seven miles south of here, on Little Beaver creek. The northward dip of the strata carries the contact below the river so that the lower portion of the somber member does not appear at the Pretty Buttes. These lower beds just above the contact are well shown, however, in the buttes and ridges back one or two miles from Little Beaver creek, where they are seen to be composed largely of sandstone. They have a very marked banded appearance, due to the alternation of dark brown and gray layers.

The dinosaur-bearing beds occur at the surface over a considerable area in southwestern Billings and western Bowman counties. They outcrop along the Little Missouri from the great bend six miles below Yule to the South Dakota line and extend back some miles on either side of the river, forming the surface formation of eighteen to twenty townships. In Billings county they extend east as far as the divide separating the headwaters of Bacon and Indian creeks from those of Deep creek.

This somber member constituting the lower Fort Union has so far yielded, according to Dr. F. H. Knowlton[1], some fifty species of plants and the list is constantly growing. As previously stated, this flora is beyond question a Fort Union flora. The following species were collected mostly in the upper portion of the somber beds, near Yule, Billings county, North Dakota:

Taxodium occidentale Newb.
Populus amblyrhyncha Ward.
Platanus Haydenii Newb.
Juglans rugosa ? Lesq.
Hicoria antiquora (Newb.) Kn.
Sapindus affinis Newb.
Viburnum Whymperi Heer.
Trapa microphylla Lesq. of Ward.
Cocculus Haydenianus Ward.

Near the mouth of Bacon creek, in the lower portion of the somber beds and associated with the dinosaur bones, a Ficus fruit was found. The same species is present in the Hell Creek beds and at Forsyth, Montana.

Five miles southwest of Yule, in section 16, T. 135, R. 105, a bed of fossil oyster shells was found, containing the single species *Ostrea subtrigonalis* E. & S.[2] Dr. Stanton considers the presence of these fossils here as sufficient evidence that the beds are not later than the Laramie. The shells were collected from about the same, or a slightly higher, horizon than the one containing the Fort Union plants, so that the testimony of the latter regarding the age of the somber beds is not in accord with that of the shells. The evidence of the plants as to the age of this member should probably have greater weight on account of the considerable number of species found in widely scattered localities.

[1] In letter to the writer.
[2] Identified by Dr. T. W. Stanton.

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The lower portion of the somber beds contains the remains of the great land reptiles known as dinosaurs, and the large bones of these animals were found in considerable numbers in the badlands at the mouth of Bacon creek. (Plate VII., Fig. 2.) The dinosaurs are an extinct group of reptiles whose members varied greatly in size, habits and appearance. Some were only three or four feet in height while others were of enormous size and were among the largest land animals which ever lived on the earth, being as much as sixty feet long. Some walked on all fours, but many had short front legs and used only their powerful hind legs for locomotion. Some were vegetable feeders, while others lived on animal food alone. One of the most common and remarkable of the dinosaurs was the clumsy and massive *Triceratops,* so called from its three horns. The animal had an enormous skull which projected backwards over the neck in a cape-like extension. It had a sharp, parrot-like beak, a stout horn on the nose, and a pair of large, pointed horns on the top of the head. It was this *Triceratops* whose remains were found in southern Billings county, along with the bones of other dinosaurs.[1]

The somber beds of southwestern North Dakota have the same relative position and are doubtless to be correlated with the "Hell Creek Beds" of Mr. Barnum Brown, including the 100 feet of "Lignite Beds" overlying them, which he regards as probably Fort Union.[2] In the Hell Creek region of Montana they rest unconformably on the Fox Hills and are overlain by the typical, light gray and buff member of the Fort Union. The Hell Creek beds of that area contain the remains of many dinosaurs, among which *Triceratops* is the most abundant.

The somber beds also correspond in position with part of the "Dinosaur-bearing beds" of the Glendive region of Montana, described by the writer.[3] In the section exposed at Iron Bluff, on the Yellowstone river a few miles above Glendive, 350 feet of dark shale and sandstone rest unconformably on a white, massive sandstone and these beds, which are barren of coal, contain Fort Union plants.[4]

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[1]Identified by Mr. C. W. Gilmore of the Smithsonian Institution, who says, "the larger specimen, on account of its large size, may be tentatively referred to the species *Triceratops horridus* (?)." A fragmentary scapula was identified as pertaining to the genus *Trachodon.*

[2]Bull. Am. Mus. Nat. Hist., Vol. XXIII, pp. 829-835, 1907.

[3]Bull. No. 316, U. S. Geol. Surv., Pt. II, pp. 198-200.

[4]Dr. F. H. Knowlton in letter to the writer.

Fig. 1. Near view of the dinosaur-bearing beds of the lower Fort Union, showing the numerous large concretions. Mouth of Bacon creek.

Fig. 2. Triceratops bones, showing one of the large horns of this dinosaur.

These strata at Iron Bluff resemble the somber beds of the Little Missouri river area of North Dakota, with which they are correlated, and near Glendive Mr. Barnum Brown found in them the remains of a *Triceratops*.

FORT UNION FORMATION.

The Fort Union, which is early Eocene in age, is the surface formation over the greater portion of the region under discussion, covering all of Billings and Bowman counties except a few small areas, as shown on the accompanying map. (Pate XVIII.) It is the Fort Union also that contains the coal beds of the district.

As was stated on a previous page the beds above the marine Cretaceous rocks were for many years thought to belong either to the Laramie or Fort Union formations. Recent work in North Dakota and Montana has shown that these beds are to be referred to the Fort Union and that the Laramie is wholly absent from the greater portion of the region. The name Fort Union was first used by Dr. F. V. Hayden in 1861 to designate the group of strata, containing lignite beds, in the country around Fort Union, at the mouth of the Yellowstone river, and extending north into Canada and south to old Fort Clark, on the Missouri river above Bismarck. The Fort Union formation is known to cover extensive areas in western North Dakota, eastern Montana and adjoining portions of Wyoming and South Dakota. The rocks are shales and rather fine-grained sandstones, with beds of lignite. They are fresh-water deposits and contain a flora of nearly 400 species of fossil plants, many of which resemble those of today. Numerous fresh water shells, and some reptiles also occur in the formation.

Mention has already been made of the fact that the Fort Union rocks are readily divided into three members, the lower of which has been discussed, under the title of the "dinosaur-bearing beds." It is the middle and upper members that are described here. The difference between them is very marked and has been observed over an extensive area. The middle or buff division outcrops in the bluffs of the Little Missouri river from Yule to the northern boundary of the area under discussion, while the beds of the upper member appear in the divides, ridges and high buttes, and are generally back a greater or less distance from the valley of that stream.

The middle portion is composed of light ash gray and buff shales and sandstones while the upper is formed of beds much darker in

color, mostly a dark and somber gray, with many brown, ferruginous, sandy nodules and concretions. The contact between these two members of the Fort Union is so clearly defined that it is readily distinguished even at a distance and is traced without difficulty wherever exposed to view. Over nearly one-half of Billings county a thick coal bed, or a layer of clinker formed by the burning of the coal, occurs just at the contact of the upper and middle series. But even where the coal or clinker is absent the line of separation is easily discernable. The workable beds of coal are more numerous in the middle member of the Fort Union, there being at least ten such beds in this portion of the formation, while the upper carries only half as many. Petrified wood, which is so abundant in many places in the region, appears to be much more common in the upper series, particularly where it occurs in the form of large stumps and trunks of trees, as in the vicinity of Sully Springs.

A comparison of the lower, somber beds with the other two members of the Fort Union shows that the latter were deposited under more uniform conditions and as a result the individual layers are more persistent and widespread.

The strata of the upper two divisions of the Fort Union formation may be seen along the Northern Pacific railroad between Fryburg and Medora. From the former station to the siding at Scoria the upper member is well shown in the badlands on either side, while between Scoria and Medora the middle member appears. The upper division is absent over practically all of southern Billings county, except in the highest buttes, and is probably not present in Bowman county.

No account of the Fort Union formation would be complete without mention of the vast quantity of burnt clay or clinker which forms so conspicuous a feature of this formation wherever it occurs. Beds of this clinker varying from 5 or 6 feet to 40 feet and over can be traced for mile after mile in the bluffs bordering the stream valleys, and in the ridges and divides, while many of the low buttes are capped with this material. The heat of the burning coal has been sufficient to burn, and in many places to completely fuse to slag-like masses, the overlying clay, turning it a red or salmon pink. The term "scoria" locally applied to this burnt clay is misleading, since it is very different from the scoria of volcanoes and is of course entirely different in origin. Further reference will be made to the clinker under the discussion of the coal beds.

The character of the Fort Union formation is well shown in the following detailed sections:

Short's Ranch Section.

This section is exposed in the steep bluff about one-fourth of a mile below the ford at Short's ranch, in the southeast quarter of section 1, T. 142, R. 102.

	Feet.	Inches.
Shale and sandstone, buff and gray, on which rest the somber beds of the upper series	17	
Coal	1	6
Sandstone, fine-grained, contains some clay, buff and gray	77	
Coal	1	
Shale, gray and yellow	16	
Coal, impure, and with two thin clay seams	1	
Shale and sandstone	17	
Shale, brown	1	
Shale, gray	7	6
Coal, and some brown clay		6
Shale, blue and yellow	7	
Shale, brown, carbonaceous		8
Sandstone with some clay	6	
Shale	4	
Coal		8
Clay, gray	1	6
Coal	1	
Shale, gray and yellow	3	
Sandstone, fine, gray	8	
Coal	2	6
Shale, blue	7	6
Coal	1	8
Shale, blue, plastic	5	6
Coal, with 6-inch clay parting 3 inches above bottom	2	6
Shale, blue, plastic	3	6
Coal		5
Shale, blue, plastic	3	
Coal		9
Shale, blue	3	
Sandstone, yellow and gray, fine-grained and laminated.	4	
Coal		1
Clay, gray		6
Coal, with 1 inch clay parting		9
Shale, bluish gray	4	
Shale, gray and brown, with a thin streak of coal		4
Sandstone, yellow and gray	3	
Shale, light gray, growing sandy above		16

	Feet.	Inches.
Shale, brown		4
Coal		18
Shale, light gray, with thin streak of coal		13
Sandstone, gray	3	
Shale, blue and yellow		8
Sandstone, yellow and gray	4	
Shale, sandy and finely laminated	1	4
Shale, blue		3
Coal		3
Clay		7
Coal		6
Sandstone, growing clayey above	2	
Shale, bluish gray, with thin streak of coal	6	
Sandstone, gray	5	
Coal	1	2
Shale, sandy, yellow	6	
Coal, with some brown clay		4
Shale, sandy and laminated toward top	14	
Coal		2
Shale, gray	3	6
Coal and brown clay		1
Sandstone, fine and gray	1	6
Shale, gray	2	
Shale, brown, with 2 to 4 inches of coal at base		8
Shale, light gray	2	8
Sandstone, gray, fine-grained, with hard ledge of rock near top; exposed above river	14	
	288	3

The beds appearing in the above section all belong to the middle member. It will be noted that although there are 17 coal seams none are of workable thickness, the thickest being only 30 inches. But the thick bed which outcrops less than two miles above and below the point where the section was made cannot here be far below river level.

The section which follows was measured three miles east of the previous one, in the northeast quarter of section 4, T. 142, R. 101., and lies wholly in the upper division of the Fort Union, its base resting on the lower member.

Section 3½ miles east of Short's Ranch.

	Feet.	Inches.
Sandstone and shale in alternating layers, more argillaceous at the base	80	
Coal band, thin		

	Feet.	Inches.
Shale, sandy	10	
Shale, bituminous	2	
Shale, sandy	10	
Powdery material, probably weathered, shaly coal.		
Shale, gray, forming where wet a sticky mud, sandy near middle	25	
Coal in two beds, the upper 1 foot, the lower 1-½ feet, separated by 4 inches of brown shale	2	10
Shale, gray, with hard, concretion-like masses of same color	55	
Coal	2	
Shale, sandy, gray	10	
Coal	1	
Shale, sandy, gray, more clayey above and below	50	
Coal	3	6
Sandstone and sandy, gray shale, rather coarse sandstone near center, fine-grained at top and bottom, with yellow bands	55	
Coal	1	
Sandstone, clayey, bluish gray, contains irregular ironstone bands, rather coarse sand at base, but grows gradually finer till at top it is a shale	40	
Coal, impure	1	3
Shale, gray	7	
Coal, impure	3	
	358	7

The light colored beds of the middle member of the Fort Unicn are well exposed in the river bluff at Medora, where the following section occurs:

Medora Section

	Feet.	Inches.
Sandstone, clayey, gray and yellow, finer grained than rock below	10	
Sandstone, gray, soft, coarse-grained, massive, forms vertical escarpment near top of bluff	35	
Coal and carbonaceous shale		1-4
Shale, gray and yellow	7	
Coal		3-4
Shale		6
Sandstone, clayey, fine-grained, gray	5	
Shale, yellow	1	6
Coal		6
Shale, gray	1	
Shale, sandy, gray	5	
Shale, gray	1	6

	Feet.	Inches.
Shale, brown, carbonaceous, with thin coal seam	1	
Shale, gray	4	
Sandstone, clayey, gray and buff, fine-grained, laminated; in places forms hard ledge projecting beyond softer clays above and below	10	
Shale, with some sandy streaks, gray and yellow	5	
Shale, brown, with plant impressions		4
Coal	1	6
Shale, gray and yellow, with sandy layers and a thin streak of coal	25	
Shale, sandy and passing toward the top into a hard, compact, fine-grained, gray sandstone, which forms a projecting ledge	3-4	
Shale, gray and yellow	5	6
Sandstone, fine-grained	2	
Shale, gray and yellow	4	6
Shale, sandy, gray fine-grained	5	
Coal streak, and brown, carbonaceous clay		1-2
Sandstone and sandy clay, gray, in places the sand is cemented into hard rock, forming a projecting ledge	7	
Shale, gray	1	
Shale, brown		8
Coal	1	
Shale, gray and yellow	20	
Shale, brown, carbonaceous	2	
Coal	4	
Shale, brown, with abundant plant remains, mostly stem impressions	1	
Shale, gray	3	
Sandstone, fine-grained and sandy shale	16	
Shale	4	
Shale, sandy	6	
Shale, gray	1	
Coal		2
Shale		2
Coal.............	8	
Shale		3-5
Coal		11
Shale and sandstone, not well exposed, to river	40	
	251	6

Large collections of Fort Union leaves were made from two horizons represented in the above section, namely, 15 feet above the 8-foot coal bed and 6 feet above the 4-foot coal bed. The fossil plants occur in a compact, hard, calcareous clay which forms lenticular masses in the softer beds.

The beds of the upper member of the Fort Union occur in Sentinel Butte, where the following section appears:

Sentinel Butte Section.

	Feet.	Inches.
Clay, calcareous	10	
Limestone alternating with calcareous clay. The limestone is very compact and fine-grained, brittle, siliceous, and gray and white in color, weathering into very thin laminae. Contains fish remains	5	
Clay, very calcareous, gray weathering to greenish	25	
Sandstone, gray, hard	80	
Shale, sandy, gray and yellow	30	
Shale, brown, with thin seam of coal	1	6
Shale, sandy, gray and yellow	53	
Coal		6
Sandstone, fine-grained, clayey	12	
Shale, brown and gray, containing many selenite crystals	4	
Sandstone, soft, fine-grained	1	
Coal		12–18
Shale, brown and carbonaceous	1	
Shale, bluish gray	10	
Sandstone, gray	12	
Shale and sandstone, not well exposed	55	
Coal		2–6
Shale, sandy, gray	37	
Shale, gray, with no sand	2	
Coal	6	
Shale, sandy, brown at the top	5	
Sandstone, fine, gray	4	
Shale, sandy, gray, containing nodules	15	
Sandstone, finely laminated	4	
Shale, sandy, gray, with ferruginous bands	8	
Shale, sandy, brown	1	
Shale, gray	5	
Shale, gray, sandy, containing abundant siliceous and ferruginous nodules, arranged mostly in bands at certain horizons; these hard nodules project from surface of softer shale and cap small clay columns	25	
Sandstone and shale, not well exposed	25	
Coal	21	2
Unexposed to level of railroad at station of Sentinel Butte	190	
	650	2

The upper three members of the above section belong to the Oligocene formation. The 21-foot coal bed is about 50 feet above

the base of the upper division of the Fort Union. Dr. A. C. Peale and Dr. F. H. Knowlton collected leaves from five horizons in Sentinel Butte, all of these plants being characteristic of the Fort Union.

There is a bed of coal not far below the upper sandstone capping the butte, which does not appear in the above section, unless it is represented by the carbonaceous clay and coal seams 30 feet below the thick upper sandstone. A thick layer of red burnt clay formed by the burning of this coal shows at several points.

Tepee Butte Section.

One of the best exposures of the Fort Union beds anywhere in the region, and that showing the greatest vertical thickness of strata, occurs in the high, steep bluff of the Little Missouri, which is surmounted by the so-called Tepee Buttes. (Plate VI, Fig. 2.) It is one and a half miles north of the mouth of Deep creek, in the southwest quarter of section 5, T. 136, R. 102.

	Feet.	Inches.
Sandstone, with hard ledge at top, to top of Tepee Buttes	35	
Shale, sandy, buff colored	17	8
Coal	4	6
Shale, dark colored	10	
Shale, buff	4	6
Shale, dark colored	7	
Sandstone, brown, with many ferruginous concretions	23	
Shale, buff, compact	31	9
Shale, chocolate brown		9
Coal	2	1
Shale, chocolate brown		5
Shale, dark colored	14	2
Shale, chocolate brown	1	
Coal	6	3
Shale, light gray	3	2
Sandstone	11	
Shale, dark colored	7	2
Coal		2
Shale, dark colored	2	2
Shale, chocolate brown	1	3
Coal		7
Shale, chocolate brown	1	
Bed R Coal	2	
Shale, chocolate brown		2
Coal	3	
Sandstone grading into shale	23	10
Shale, carbonaceous		5

	Feet.	Inches.
Shale, dark colored	9	8
Shale, sandy, buff	2	2
Shale, chocolate brown		11
Shale, sandy, buff	9	1
Shale, dark colored	2	3
Sandstone, fine, compact, brown	6	4
Coal		3
Shale	3	3
Shale, chocolate brown		4
Shale, buff	2	8
Shale, with streaks of coal	1	1
Sandstone, grading into shale	18	
Shale, and some coal	1	2
Sandstone, grading into shale	9	
Coal		6
Shale, chocolate brown		8
Coal		1
Shale, chocolate brown		2
Coal		1
Shale, carbonaceous		4
Shale, sandy, light gray	7	
Shale, chocolate brown		5
Shale, sandy	15	2
Coal		3
Shale		9
Coal		5
Shale, chocolate brown		6
Coal	1	7
Shale	1	2
Coal		3
Shale, sandy, grading into pure shale	16	
Shale	2	
Coal		6
Shale, buff	1	
Coal		2
Shale, sandy	8	5
Shale, chocolate brown		2
Coal	1	6
Shale, chocolate brown	1	
Sandstone, argillaceous, buff	13	7
Coal		8
Shale, chocolate brown		4
Shale, sandy, buff	5	6
Shale, black, carbonaceous		3
Sandstone	6	2
Shale, black carbonaceous		2
Shale, sandy	1	

	Feet.	Inches.
Shale, chocolate brown		9
Shale, sandy, buff	3	3
Shale, brown	1	
Sandstone, argillaceous, buff	7	
Sandstone, grading into shale, gray	12	
Shale, buff	7	1
Sandstone, buff	2	
Sandstone, argillaceous, buff	2	
Shale, chocolate brown		10
Shale, buff	2	6
Shale, black, carbonaceous	3	
Shale, chocolate brown	2	
Shale, buff	1	
Shale, brown, carbonaceous	1	6
Sandstone, gray	2	6
Shale, chocolate brown	2	8
Coal	2	2
Shale, chocolate brown	1	
Shale, buff, sandy	1	
Sandstone, fine-grained	3	3
Coal		2
Shale sandy, buff	2	
Sandstone, buff	4	7
Coal	1	4
Shale, chocolate brown		3
Coal		6
Shale, chocolate brown		6
Coal	9	4
Shale, chocolate brown		2
Shale, sandy, buff	5	
Sandstone, buff	26	
Coal	2	2
Shale, brown		2
Coal	2	8
Shale	1	
Coal		8
Shale, dark brown, carbonaceous		3
Shale, sandy	2	6
Sandstone, grading above into clay, buff	17	6
Shale, chocolate brown		6
Coal		10
Shale, chocolate brown		6
Coal	1	6
Shale, chocolate brown		2
Coal	3	2
Shale		1
Coal	1	8

	Feet.	Inches.
Shale, brown and buff	2	6
Shale, dark colored	11	8
Shale, blue	5	9
Sandstone, buff	49	6
Coal		4
Shale, sandy		11
Sandstone, brown		4
Shale, dark colored		10
Coal	1	8
Sandstone, buff, coarse	3	3
Sandstone, fine-grained, to river level	8	10
	584	

The upper 183 feet of the above section, or all that portion above coal bed R, belongs to the upper member of the Fort Union.

These sections, taken from widely separated localities, show that this formation is composed of alternating beds of sandstone and shale with occasional beds of coal. The top of the Fort Union is formed of a rather hard sandstone 80 to 100 feet thick. This sandstone appears as the topmost layer in many of the high buttes of Billings county, as in Bullion, Sentinel, Flat Top and Black buttes. (Plate VIII, Fig. 1.) It forms vertical cliffs about their summits and huge blocks and masses breaking off from time to time accumulate at the base of the cliffs in great talus heaps. On Sentinel Butte and in White Butte the Oligocene beds are seen resting directly on this uppermost sandstone of the Fort Union. The base of the middle member appears along the Little Missouri river in the vicinity of Yule and for four or five miles below. The light colored beds forming the middle portion of the Fort Union are here seen resting on the dark, somber beds of the lower member.

Thickness of the Fort Union formation. The thickness of the upper two members is not far from 1000 feet. In Sentinel and Bullion buttes, where the entire thickness of the upper division occurs, it measures about 500 feet, and the thickness of the middle portion is approximately the same. In the Tepee Butte section 400 feet of the middle beds are exposed above the river, and the base of the section is believed to be not far from 100 feet above the bottom of the light gray and buff beds. Including the dinosaur-bearing beds the total thickness of the Fort Union is about 1600 feet.

As previously stated, the Fort Union contains a flora of nearly 400 species and a fauna comprising shells and reptiles. The fossil

plants collected in the area under discussion were found mostly in the middle member of the formation and came from widely scattered localities. The following are a few of the species occurring in the Fort Union beds:[1]

Elk creek, near the Stone ranch.
 Equisetum sp.

Mouth of Deep creek.
 Viburnum Newberrianum Ward.
 Viburnum asperum Newb.

Cedar canyon, two miles southwest of Medora.
 Sequoia Nordenskioldi Heer.
 Populus cuneata Newb.
 Ulmus planeroides Ward.
 Populus Richardsoni Heer.
 Populus amblyrhyncha Ward.
 Sapindus grandifoliolus Ward.
 Viburnum antiquum (Newb.) Hol.
 Populus daphnogenoides Ward.
 Populus glandulifera Heer.
 Planera microphylla Newb.
 Carpites n. sp.
 Taxodium occidentale Newb.
 Diospyros brachysepala Al. Br.

Divide between Magpie creek and Knife river.
 Taxodium occidentale Newb.
 Pterespermites Whitei? Ward.

T. D. ranch, at mouth of Beaver creek.
 Viburnum Newberrianum Ward.

One mile above Mikkelson.
 Diospyros—may be *D. ficoidea* Lesq. or new.

Near mouth of Bear creek.
 Populus cuneata Newb.

One mile south of McKenzie county line in bluffs of Little Missouri.
 Platanus nobilis Newb.
 Viburnum antiquum (Newb.) Hol.
 Viburnum Whymperi? Heer.
 Corylus rostrata? Ait.

Custer Trail ranch, near Medora.
 Asplenium tenerum.

[1]Identified by Dr. F. H. Knowlton.

Near the base of Black Butte, and probably in the upper member of the formation, Mr. Earl Douglass collected the following plants, which were identified by Dr. F. H. Knowlton: *Asplenium* (a fern), *Equisetum* (horse-tail), *Populus* (poplar), *Thuja* (arborvitae), *Celastrus* (bitter sweet) and others.

Thirteen species of fresh water shells have been collected in the Fort Union beds of Billings county, and these were identified by Dr. T. W. Stanton. They comprise the following:

Near mouth of Bear creek in section 4, T. 137, R. 102.

Corbula mactriformis M & H.
Unio priscus M. & H.

Near the Moore ranch on Beaver creek, section 32, T. 144, R. 103.

Campeloma producta White.
Viviparus retusus M & H.
Viviparus leai M & H.
Thaumastus limnaeiformis M. & H.

About 3 miles below Mikkelson.

Campeloma multilineata M & H.

Near the mouth of Beaver creek.

Corbula mactriformis M. & H.
Viviparus trochiformis M. & H.
Viviparus leai M. & H.
Viviparus retusus M. & H.
Thaumastus limnaeiformis M. & H.

Near old Weidman ranch on Beaver creek, section 15, T. 144, R. 103.

Campeloma multilineata M. & H.
Campeloma producta White.
Viviparus leai M. & H.
Viviparus trochiformis M. & H.

Young ranch on Little Missouri river, section 22, T. 143, R. 102, 20 feet above upper coal bed.

Campeloma multilineata M. & H.

Roosevelt's old Elkhorn ranch, section 33, T. 144, R. 102.

Sphaerium formosum M. & H.
Bulinus longiusculus M. & H.
Micropyrgus minutulus M. & H.
Vivaparus trochiformis M & H.
Viviparus retusus M. & H.
Hydrobia sp.

Section 9, T. 144, R. 102, northern Billings county.

Unio sp.

Campeloma? sp.

The remains of vertebrates are rare except in the lower Fort Union. Several years ago a few bones were discovered in this formation by Mr. Charles Foley on the divide north of Andrews creek, in the southwest quarter of section 8, T. 140, R. 103. In company with Mr. Foley this locality was visited by A. C. Peale, F. H. Knowlton and the writer, and fragments of bones were collected in a black shale 30 feet above the base of the upper member of Fort Union. These were identified by Mr. J. W. Gidley as the bones of fishes, turtles, and the aquatic reptile *Champsosaurus laramiensis*. What is probably the same species was found by Mr. Barnum Brown in the Hell Creek beds of Montana associated with dinosaurs, and also in the overlying strata which correspond to the upper portion of the somber beds, or lower Fort Union of this report.

WHITE RIVER FORMATION.

The beds of this formation, which belong to the Oligocene, are confined to two small areas, one in southern Billings county in the vicinity of Sandcreek Post Office, the other on Sentinel Butte. In the latter locality they rest directly and conformably upon the thick sandstone which forms the top of the Fort Union. The beds occur only on the northern end of Sentinel Butte and their maximum thickness is not over 40 feet. (Plate VIII, Fig. 1.) They are clearly the remnants left by the erosion of a thicker and more extended formation which doubtless once covered a large area in this region. Where the strata are exposed in a low mound near the northwestern edge of the butte they are seen to be composed of light gray calcareous clay or marl, which contains, toward the top, beds of a nearly white, compact limestone. This limestone breaks readily into thin layers one-eighth to one-quarter of an inch thick, and some of the thicker layers become siliceous toward the center.

In one of the upper beds of this limestone are found the remains of two species of fresh water fishes. These fossil fishes were first discovered on Sentinel Butte by Dr. C. A. White, who visited the locality in 1882, and published an account of the deposit containing them.[1] They were described by E. D. Cope as belonging to a new genus and were named by him *Plioplarchus Whitei* Cope and *Plioplarchus sexspinosus* Cope.

[1] Amer. Jour. Sci., June, 1883, Third Series, Vol. XXV, pp. 411-416.

Fig. 1. The flat summit of Sentinel Butte, showing cliffs of Fort Union sandstone and mound of Oligocene beds resting on the sandstone.

Fig. 2. Contact of the Fort Union and White River formations in White Butte. The thick sandstone ledge near the middle of the slope is at the top of the Fort Union.

Fig. 1. White Butte, composed of Oligocene (White River) beds, southern Billings county.

Fig. 2. White River beds exposed in White Butte, southern Billings county.

Since the fishes were not closely related to any previously described they did not serve to indicate the age of the beds in which they were found, but upon stratigraphic grounds Dr. White referred the strata to the Green River group of the Eocene, though he was by no means confident that this was their true position. In the light of more recent discoveries it seems much more probable that these beds on Sentinel Butte belong to the White River division of the Oligocene. It is now known that less than forty miles to the southeast are other deposits which rest directly on the upper sandstone of the Fort Union and which are known from their fossils to belong to the White River group. On the other hand, no beds of the Green River group are found any nearer than southwestern Wyoming and it is not at all likely that they ever extended this far north and east, while the White River beds cover considerable areas in South Dakota and Montana.

It is strange that these beds are entirely absent from the other high buttes of this region, although they are capped with the upper sandstone of the Fort Union and search was made for them on Bullion, Flat Top and Black buttes. The extensive erosion to which this region has been subjected during many ages and which is known to have removed at least from 800 to 1,000 feet of strata over a large area, has left only a few remnants of the White River deposits.

In the vicinity of Sandcreek Post Office, in southern Billings county, the beds of this group cover an area from eight to ten square miles in extent which occupies the highest part of the divide between the headwaters of the North Fork of the Cannon Ball river, and Deep and Sand creeks. They form the conspicuous, snow white elevations, known as White Butte or Chalk Butte. (Plate IX, Fig. 1.) Erosion has here left two narrow ridges about two miles apart, extending nearly north and south, the western three miles long and the eastern less than two miles in length, with a general elevation of 300 to 400 feet above the surrounding plain. Three miles to the west, on the opposite side of the valley of Sand creek, Black Butte rises 450 feet above the creek, being capped by the same sandstone as that forming the top of the other high buttes of the region. But the beds of the White River group are wanting on Black Butte, although occurring at a considerably lower level only three miles to the east. In White Butte they are, however, found resting directly on the thick upper sandstone of the Fort Union, which outcrops at

several points near the base of the western slope of the western ridge and also at its northern end. (Plate VIII., Fig. 2.) This sandstone here dips strongly to the east so that within a distance of three miles its dip carries it from the top of Black Butte to the base of the ridge on the opposite side of the valley, where it is over 200 feet lower.

The following is a general section of the White River beds as they occur in White Butte:

White Butte Section.

		Feet	Inches
11.	Sandstone, rather fine-grained, light greenish gray in color, weathering into a greenish sand; to top of White Butte	105	
10.	Clay, gray to light greenish color ....20 to	25	
9.	Clay, hard and compact, calcareous, light gray, almost white; forms hard ledges which make low vertical cliffs towards the top of the butte, and weathers very irregularly	34	
8.	Clay, dark gray, calcareous; the line of separation between this clay and No. 7 is sharp and distinct, the clay being considerably darker than the underlying sandstone	46	
7.	Sandstone, light gray, rather coarse-grained	20	
6.	Sandstone, very coarse-grained and pebbly; in places the pebbles are so abundant as to form a conglomerate. Shows cross-lamination. Pebbles composed of quartz, silicified wood, many varieties of igneous rock, among which porphyry is common, etc. Pebbles range in size up to 2 and 3 inches in diameter	26	
5.	Clay, very light gray, slightly sandy	5	
4.	Sandstone, light gray, very fine-grained and argillaceous	5	4
3.	Clay, light gray to white, slightly darker than No. 2; contains some fine sand	10	6
2.	Clay, very white and pure	6	6
1.	Clay, white, containing some fine sand, hard and very tough when dry; rests directly on the sandstone of the Fort Union	14	4
		298	

In No. 8 of the above section was found the skull of an extinct species of ruminant, *Eporeodon major* (?), which is found in the Oreodon beds of the Oligocene.[1]

[1]Identified by Mr. J. W. Gidley.

Fig. 1. The coarse sandstone of the lower member of the White River beds in White Butte, showing effects of rain erosion.

Fig. 2. The pebbly sandstone of the lower member of the White River beds exposed in White Butte.

It will be seen from the section just given that the White River group is here composed of white clays at the bottom, on which rest a coarse sandstone which in places is filled with large pebbles; this is overlain by about 100 feet of calcareous clays which in turn are overlain by more than 100 feet of fine-grained, greenish sandstone. (Plate X, Figs. 1 and 2.)

These deposits represent all three divisions of the White River group, the lower or Titanotherium beds, the middle or Oreodon beds, and the upper or Protoceras beds. In the foregoing section Nos. 1 to 7 probably belong to the lower, Nos. 8 to 10 to the middle, and No. 11 to the upper division.

From the middle and upper horizons Mr. Earl Douglass in the summer of 1905, collected many fossil mammals.[1] Among these were the remains of many rhinoceroses, including very complete skulls, and several three toed horses. The remains of crocodiles were also found. The rhinoceroses belong to the species *Acerathcrium tridactylum* Osborn and the horses to the two species *Mesohippus bairdi* (Leidy) and *Mesohippus brachystylus?* Osborn.

It was undoubtedly this same White Butte area which was discovered by Professor E. D. Cope in September, 1883. The discovery was announced in a letter written from Sully Springs, Dakota, and read before the American Philosophical Society.[2]

The following is a portion of this letter: "I have the pleasure to announce to you that I have within the last week discovered the locality of a new lake of the White River epoch, at a point in this Territory nearly 200 miles northwest of the nearest boundary of the deposit of this age hitherto known. The beds, which are unmistakably of the White River formation, consist of greenish sandstone and sand beds of a combined thickness of about 100 feet. These rest upon white calcareous clay, rocks, and marls of a total thickness of 100 feet. These probably also belong to the White River epoch, but contain no fossils. Below this deposit is a third bed of drab clay, which swells and cracks on exposure to weather, which rests on a thick bed of white and gray sand, more or less mixed with gravel. This bed, with the overlying clay, probably belongs to the Laramie period, as the beds lower in the series certainly do.

The deposit as observed does not extend over ten miles in north and south diameter. The east and west extent was not determinea."

Then follows a list of 20 species of vertebrates which were col-

[1] Annals of the Carnegie Museum, Vol. IV, Nos. III and IV, 1908, pp. 265-271.
[2] Proc. Amer. Philos. Soc., 1883, Vol. 21, pp. 216-217.

lected from this locality, including two species of fishes, tortoises (Trionyx), rhinoceroses and several Oreodons. The white calcareous clay below the upper sandstone is now known to carry fossils and the sand below this clay is also probably to be included with the White River group, as already indicated on a previous page. Professor Cope, in common with other geologists at that time, regarded the underlying beds as belonging to the Laramie, but as already stated, they are now on the basis of their plant remains known to be Fort Union in age.

Mr. Douglass in 1905 discovered another deposit of White River beds about 30 miles north and east of White Butte, in Stark county. The area, which is known as the "Little Bad Lands," lies some 12 to 16 miles southwest of Dickinson. All three divisions of the White River group are here present and a number of mammalian remains were collected. The nearest White River areas to the south are those mentioned by Professor J. E. Todd as occurring in northwestern South Dakota in the Cave Hills and Slim Buttes. The former locality is only about 35 miles from White Butte.

These Oligocene beds are believed to be in part lake deposits and in part river deposits. The lack of uniformity, the cross-bedding, and the coarseness of the materials of some portions of the formation seem to be the result of deposition through river action. Other portions were apparently laid down in the more quiet waters of a lake. It is not possible to determine at the present time whether the beds of the three North Dakota areas were deposited in one large lake covering a considerable tract in Billings and Stark counties, or whether they were accumulated in several small lakes. After their formation they were subjected to great and long continued erosion, which has removed all but these few small remnants of the Oligocene beds.

During the summer of 1905 Mr. Earl Douglass spent some time in the White Butte region making collections for the Carnegie Museum at Pittsburg. Through the kindness of Dr. W. J. Holland, Director of the Museum, and of Mr. Douglass, the writer was allowed to read the report in manuscript giving the results of the investigations, and wishes to express his great appreciation of the courtesy thus extended.

Mr. Douglas made a more detailed section of the White River beds than that given on a previous page, in which he includes lists of the mammalian remains discovered by him. This section is quoted

from his report, soon to be published by the Carnegie Museum. It is made from the eastern slope of the eastern portion of White Butte, and extends from one of the lowest exposures to the base of the upper division of the White River group.

Section of White River Beds at White Butte.

9. Gray sand, probably with a mixture of volcanic ash . . . . 6 ft.
8. Clay or other fine material . . . . 3 ft.
7. Cream colored fine sandy clay . . . . 1 ft.
6. Nodular "Oreodon beds"—clay gray to light cream-colored on surface, darker cream-colored inside. Nodules brownish, cellular, sometimes containing bones, especially in lower portion. Beds sparingly fossiliferous from top to bottom. *Ictops, Ischyramys, Palaeolagus, Merycoidodon culbertsoni, Leptomeryx evansi, Mesohippus, Hyracodon, Aceratherium,* etc. . . . . 35 ft.

Middle White River.

5. A band of rock which weathers gray on the surface, becoming more nearly cream-colored toward the top, at the base of the Oreodon beds. Some thin layers are very compact. Bones black. *Merycoidodon,* etc. . . . . 15 ft.

4*c*. A mixture of hard and soft rock (siliceous clay) weathering into tough, compact masses.

b. Tough rock with one seam containing nodules of barite.

a. Rock, white or gray at the bottom, with imperfect horizontal fractures or division planes. . .25 to 30 ft.

3. Yellowish sand with fine and coarse grains mixed with clay and having a slightly saline (?) taste. White on weathered surfaces. When the coloring matter and the fine clay are washed out it leaves a very clean sand, composed principally of clear quartz grains, which have been imperfectly rounded by the action of wind or water. . . . . 80 ft.
2. Thinly and horizontally laminated clay and fine grit. The lighter laminae are light gray, the darker of a bluish tint. These laminae alternate irregularly on the weathered surface; they also unconformably overlie the brownish sand beneath. At the bottom of a trough-like depression there are two or three thin bands of iron-stained material about ⅛ inch in thickness. In tracing this upward it was sometimes laminated and sometimes massive. Part of it is gray sandstone, and the structure makes it appear as if part of the mass had been deposited in an uneven surface of the other portion. Scattered

Lower White River.

over the surface of the darker gray portion are fragments of petrified wood; rounded pebbles of white quartz; granite; granitic rock without mica; gray, bluish-gray, brown, and reddish quartzite of compact texture; and gray, brown, reddish, purplish, and bluish cellular pebbles, some of which look like volcanic material, but are mostly granular rock, some of the crystals of which have been dissolved. There fragments vary in size from that of fine sand to large pebbles, some of which are six inches in diameter. There are also flat, flinty fragments which contain impressions of plants... 35 ft.

1. Lowest exposure found at this place. A brownish-gray iron-stained, homogeneous sand with small, brown concretionary masses. Upper surface not level, but having depressions filled with No. 2. 5 ft.

Total thickness of section, 210 ft.

Another section from another locality on White Butte partly supplements the one just given as it extends upward through the Upper White River beds. Its lowest member corresponds with No. 5 of the preceding section, beginning with the top of the Titanotherium beds and extending upward through the Oreodon and overlying beds as high as they are exposed at White Butte.

Section of upper portion of western ridge of White Butte.

Upper White River.

13. Green sand, mostly unconsolidated, gray sand, shale, and fragments of bones .... 18 ft.
12. Green sand. Fragments of bones of Rhinoceros, etc. .... 8 ft.
11. Green sandstone, unequally hardened so that it contains irregular cavities (weathered pits) and root like rods .... 8 ft.
10. Green sand with some nodules, gray on surface near top .... 38 ft.
9. Gray shale, hard in places, sometimes greenish in color. Bones of Rhinoceros .... 24 ft.
8. "Rubbly" sandstone in rounded egg-shaped forms .... 4 ft.
7. Harder sandstone than No. 6 .... 5 ft.
6. Fine greenish sand and clay, in one stratum cracking vertically. Some imperfect horizontal parting planes .... 12 ft.
5. Green sand with sandstone concretions....... 6 ft.
4. Green and gray clay shales .... 6 in.
3. Fine gray sand, with some clay. *Merycoidodonts, Hyracodonts, Mesohippus,* etc. .... 12 ft.

	2. Pinkish-gray clay with brown cellular nodules. "Oreodon Beds" *Ictops, Gymnoptychus, Eumys, Ischyromys, Palaeolagus, Mesohippus, Hyracodon, Aceratherium, Merycoidodonts, Leptomeryx,* etc. .... 32 ft.
Middle White River.	1. Tough sandy clay with appearance of stratification, without brown nodules, but containing a few remains of Merycoidodonts. Probably belongs to "Oreodon" horizon . ... 6 to 8 ft.
	Total thickness of section .... 163 ft.
	Total thickness of beds at White Butte about 320 ft

The Oreodon beds have nearly the same appearance wherever exposed but the overlying beds are more variable, and probably no two sections would be just alike. The Oreodon beds at White Butte are not rich in mammalian remains, and most of the fossils are fragmentary, though in one place three skulls with portions of skeletons of *Merycoidodon,* and a skull with part of a skeleton of *Ictops* were found. In No. 3 of the last section, portions of skulls of *Merycoidodonts* were obtained but probably of different species from that of the nodular beds. No. 5 contains many remains of *rhinoceroses.* Two good skulls were found which have been referred to *Aceratherium tridactylum.* Some fragments of bones and teeth of reptiles and mammals, including jaws of rodents and the tooth of a crocodile were found in No. 6. Fragments of bones were found in most of the higher horizons.

ALLUVIAL DEPOSITS.

The youngest of the formations occurring in southwestern North Dakota are the recent alluvial deposits of the stream valleys. They are of comparatively small extent, although along the Little Missouri river and some of the larger streams extensive flats or low terraces are covered with sediment laid down during times of flood. These deposits, composed of sand and sandy clay form the rich soils of the valley bottoms. The strip of alluvium along the Little Missouria varies in width from one-half to one mile and more. It is widest where large tributary valleys join the main one.

Billings and Bowman counties were not affected by the continental ice sheet which covered the greater portion of the state and left behind the drift deposits. No glacial materials are found in this region.

STRUCTURE.

The geological structure of the region under discussion is very simple, the beds being nearly horizontal over most of the area and having undergone little folding since their deposition. Reference has already been made on a previous page to the anticline which has brought the Pierre shale to the surface in northwestern Bowman county.

This anticlinal fold is probably a continuation of the one so well shown on the Yellowstone near Glendive, the axis of which has a trend S. 38 degrees E. As a result of this disturbance the strata over a large territory have been slightly tilted and given a gentle dip toward the north and east. As might be expected, this dip is not uniform over the entire region, but is greater in some places than others. Thus the average dip between Marmarth and Sentinel Butte is approximately 20 feet to the mile, while for several miles on Little Beaver creek the dip is 50 feet per mile, and in the vicinity of Yule there is also a dip to the northeast of 50 feet to the mile. At Marmarth the base of the somber beds is not far from 2,600 feet above sea level, and at Sentinel Butte the top of the middle series of the Fort Union lies 2,840 feet above sea level; in other words the same strata are nearly 850 feet lower at Sentinel Butte than at Marmarth. From Sentinel Butte to Medora there is a dip toward the east of 23 feet per mile, while from Bullion Butte to Medora the dip toward the north is 16 feet to the mile. North of Medora the dip of the beds is considerably less, being not over 3 to 5 feet to the mile on the average, and the strata are slightly undulating.

The unconformity between the Fox Hills formation and the somber beds has already been mentioned in connection with those formations. It is well shown at two points on Little Beaver creek, in section 7, T. 132, R. 106. Here the massive sandstone forming the top of the Fox Hills is seen to have undergone erosion before the deposition of the brown and black, highly carbonaceous and argillaceous sandstone, which shows cross-limitation in places. Some of the depressions of the former land surface have been eroded to a depth of 6 feet below the adjoining elevations.

THE COAL DEPOSITS.

CHARACTER AND EXTENT.

Almost the entire area under discussion is underlain by workable beds of coal. The only districts where no coal is found are eight or

ten townships in western Bowman county, and several townships in southwestern Billings county, where the barren somber beds occur at the surface. Outside these restricted areas it is probable that a hole put down in any portion of the region would strike one or more workable coal beds.

The Little Missouri badlands afford exceptionally favorable opportunities for the study of the coal deposits on account of the great number of outcrops, which make it possible to trace individual beds almost continuously over extensive tracts. It is thus possible to correlate and place in their relative positions in the vertical section coal beds which outcrop in widely separated portions of the field. The number of workable coal beds in southwestern North Dakota is now known to be at least 21, not all of them being present at any one point, but some occurring in one locality and some in another. They are distributed through from 1,000 to 1,300 feet of strata and range from 4 to 35 feet in thickness. The aggregate thickness of the coal in these 21 beds is 157½ feet.

It was formerly supposed that the lignite beds were not of great extent and covered but comparatively small areas, one seam thinning out and being replaced by others at a different horizon. But the detailed work of the past two years has shown that some of the individual coal beds cover large areas. One, with a thickness varying from 5 to 16 feet, has a known extent of twenty miles in one direction and twenty-five in another, with an area of at least 500 square miles, and probably much greater. Another bed of coal was traced 36 miles north and south and 24 miles east and west, and while its known area as shown from outcrops is nearly 900 square miles, it undoubtedly has an extent of 1,000 to 1,500 square miles. This coal bed, which had a thickness ranging from 9 to 15 feet and over, has been largely burned out or removed by erosion, but still underlies a number of townships. Other beds of coal are much less persistent and the area covered by them is comparatively small.

The coal beds vary in thickness from less than an inch to 35 feet. There are at least 6 which have a thickness of 10 or more feet and three which measure over 20 feet. The thickest is the 35-foot bed which outcrops on Sand creek; the Bacon creek bed is 30 feet and the Sentinel Butte bed is 21 feet thick. Beds of coal from 4 to 8 feet thick are common.

The coal of southwestern North Dakota, as of the rest of the state, is mostly a brown lignite with a decidedly woody structure, exhibiting clearly the grain of the wood and having the toughness of that material. It breaks or splits readily along the grain but is broken with difficulty in any other direction. Portions of flattened trunks and branches are often found in the beds, bearing a close resemblance to the original wood except for the brown color. The same bed is frequently more woody in some portions than others, being made up of alternating layers of tough brown lignite, and black, lustrous, brittle material.

In one outcrop the sandy clay under the coal was filled with the roots of the trees which had formed the seam. These roots ran down into the clay three or four feet and some were several inches in diameter. They were largely changed to coal but still had the appearance of roots.

In many of the beds the coal is cut by one or two systems of joints which are vertical, or nearly so, and from five or six inches to one foot and more apart. These joints are usually very clear cut and regular. On exposure to the air the lignite loses part of its moisture, begins to crack, and finally breaks up into small fragments. This change takes place much more readily in the coal of some beds than in that of others. A number of outcrops were observed in which the material must have been exposed for many months, but back several inches from the face the coal still had the appearance of being fresh and little affected by the weather. On the other hand, some beds after no longer period of exposure, show the effects of weathering for a distance of several feet from the surface.

Many of the coal beds have been burned out over large areas and there are very few which have wholly escaped burning. Some were doubtless set on fire by man, others may have caught from prairie fires, but it seems probable that spontaneous combustion has been the chief cause.

This burning of the coal beds has doubtless been going on for many thousands of years, ever since the erosion of the overlying strata brought them near the surface or exposed them in the bluffs and buttes. Once started, the fire slowly smoulders and works its way back farther and farther from the outcrop, the overlying clays settling down as the coal is consumed and the cracks thus opened admitting fresh supplies or air. (Plate XI, Fig. 2.) Thus a coal bed which is not too far below the surface may continue to burn

Fig. 1. A mass of burnt clay or clinker formed by the burning of a thick coal bed. Mouth of Deep creek.

Fig. 2. A burning coal bed. The surface over the coal has settled down many feet and ground is broken by wide cracks from which the gases escape.

for a long period and instances are known where beds have been on fire for at least twenty years. It seems improbable that this coal can burn very far back from the outcrop when covered by any considerable thickness of shale or sandstone, for after the coal has been consumed these would settle down and occupy its place, thus shutting off the air and smothering the fire. It seems likely, therefore, that those beds of lignite which have burned out over many square miles must have been near the surface, as we find them today, when they were being consumed.

The heat thus produced has changed the overlying clays, and either burned them to a red or pink clinker, or entirely fused them into slag-like masses. These clinker beds often have a thickness of forty to fifty feet and over and are a very conspicuous feature not only of the badlands, but of the upland prairie as well. In some instances where two coal beds are not over thirty or forty feet apart the clinker produced by each may form but a single layer, the entire thickness of intervening clays being burned. (Plate XI., Fig. 1.)

ANALYSES.

The following analyses show the composition of the brown lignite of North Dakota. The analyses were made under the supervision of N. W. Lord at the fuel-testing plant of the United States Geological Survey at St. Louis by F. M. Stanton, Chief Chemist:

	No. 1	No. 2	No. 3	No. 4
Moisture	43.78	29.78	38.45	28.09
Volatile combustible	26.07	32.31	28.02	37.78
Fixed carbon	26.33	31.35	27.84	27.86
Ash	3.82	6.56	5.69	6.27
Sulphur	.61	.88	.54	.72

No. 1. The 35-foot bed on Sand creek, section 31, T. 135, R. 101, Billings county.
No. 2. The 21-foot bed in Sentinel Butte.
No. 3. The 9-foot bed mined at Medora.
No. 4. Near Cartwright, McKenzie county.

Both ultimate and proximate analyses were made of the coal from three North Dakota mines with the following results:[1]

Brown lignite from Lehigh mine, Consolidated Coal Company, Lehigh. This sample consisted of run of mine, and was shipped under the supervision of M. R. Campbell, of the United States

[1] Bull. No. 290, U. S. Geol. Surv., pp. 135—139.

Geological Survey. Two mine samples were taken at widely separated points in the mine for chemical analysis.

	Mine samples		Car sample
Air-drying loss	35.60	33.90	10.40
Proximate: Moisture	42.06	42.81	32.64
Proximate: Volatile matter	24.55	26.84	29.19
Proximate: Fixed carbon	25.73	23.93	26.75
Proximate: Ash	7.66	6.42	11.42
Ultimate: Sulphur	1.13	.96	3.54
Ultimate: Hydrogen	.....	.....	6.15
Ultimate: Carbon	.....	.....	39.53
Ultimate: Nitrogen	.....	.....	.49
Ultimate: Oxygen	.....	.....	38.87
Calorific value determined:			
Calories	3421	.....	3872
British thermal units	6158	.....	6970

Brown lignite from mouth of Cedar Coulee, four miles southeast of Williston, furnished by the engineers of the United States Reclamation Service. This sample consisted of run-of-mine coal. Mine sample was taken from this mine for chemical analysis.

	Mine sample	Car sample
Air-drying loss	33.10	17.30
Proximate: Moisture	41.13	36.13
Proximate: Volatile matter	27.17	29.28
Proximate: Fixed carbon	26.34	29.55
Proximate: Ash	5.36	5.04
Ultimate: Sulphur	.72	.59
Ultimate: Hydrogen	.....	6.60
Ultimate: Carbon	.....	42.00
Ultimate: Nitrogen	.....	.73
Ultimate: Oxygen	.....	45.04
Calorific value determined:		
Calories	3603	4070
British thermal units	6485	7326

Brown lignite from the Wilton mine, Washburn Lignite Coal Company, one mile east of Wilton. This sample was made up of lump lignite and was shipped under the supervision of M. R. Campbell, of the United State Geological Survey. The mine samples were taken at widely separated points in the mine for chemical analysis.

		Mine samples		Car sample
Air-drying loss		32.30	33.50	12.70
Proximate	Moisture	40.53	41.88	35.96
	Volatile matter	27.05	26.11	31.92
	Fixed carbon	27.37	26.73	24.37
	Ash	5.05	5.28	7.75
Ultimate	Sulphur	.76	.96	1.15
	Hydrogen	.....	.....	6.54
	Carbon	.....	.....	41.43
	Nitrogen	.....	.....	1.21
	Oxygen	.....	.....	41.92
Calorific value determined:				
Calories		3691	.....	3927
British thermal units		6644	.....	7069

The test of North Dakota lignite made at the Fuel Testing Plant of the United State Geological Survey at St. Louis to determine its value as a gas-producer fuel showed that it would be an ideal fuel for this purpose but for its tendency to clinker. It yielded a rich gas and not very much tar.

DETAILED DESCRIPTION OF THE COAL BEDS.

For the purpose of description the coal beds of the region may for convenience be divided into groups and these will be considered in the order of their occurrence from the lowest (oldest) to the highest (youngest). There are five such groups, namely, (1) the Yule group, (2) Great Bend group, (3) Medora group, (4) Beaver Creek group, and (5) Sentinel Butte group. (Plate XII.) Since the older beds occur in the southern part of Billings county, our description will begin with that district.

YULE GROUP OF COAL BEDS.

The coal beds belonging to this group are found in the vicinity of Yule, and are also exposed farther south on Bacon and Coyote creeks. All the beds included in this group occur in the somber beds forming the lower member of the Fort Union formation.

In following down the Little Missouri river from the southern boundary of the area no coal is found until two or three miles below the mouth of Cash creek. Here, in the southwest quarter of section 34, T. 135, R. 105, a coal bed (A) five feet thick outcrops in the steep bluff of the river, 65 feet above water level. So far as known this is the lowest workable bed outcropping anywhere in the region.

About two miles west of here the following section is exposed in some high buttes and ridges in the west half of section 32, T. 135, R. 105.

	Feet	Inches
Clinker layer formed by burning of a coal bed		
Shale and sandstone, mostly light gray and buff	85	
Coal, with 6-inch clay seam one foot below top	5	6
Shale and sandstone	25	
Coal	4	8
Shale and sandstone, to river	130	

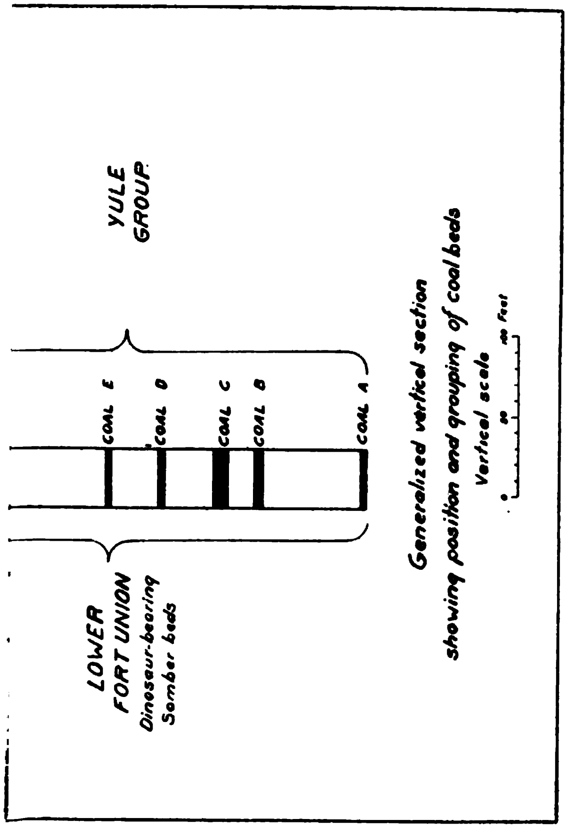
The upper of the three coal beds represented in the above section has been largely burned out in this vicinity and no measurement of it could be secured. The lower bed may be the same that outcrops two miles east of here, but this was not definltely determined.

Three miles below the mouth of Cannon Ball creek, in section 16, T. 135, R. 105, no less than seven workable coal beds are exposed on the west side of the Little Missouri river. The section here is as follows:

	Feet	Inches
Coal	4	8
Shale, with 8-inch coal seam	6	8
Coal	4	3
Shale and sandstone	75	
Bed F: Coal	8 to 9	
Shale and sandstone	40	
Bed E: Coal	3	
Shale and sandstone	20 to 30	
Bed D: Coal	2 to 4	
Shale and sandstone	12	
Bed C: Coal	8 to 10	
Shale and sandstone	10 to 20	
Bed B: Coal	6	
Shale and sandstone, to river level	50	

Coal bed B of the above section does not appear in the river bluffs below this point and probably dips below water level near here. The upper two coal beds were not seen elsewhere and are too high to appear in the bluffs bordering the valley of the Little Missouri. The four remaining coal beds exposed in the foregoing section, namely, beds C, D, E and F, appear at a number of points along the river between section 16 and Yule. Thus bed C, which in most places has a thickness of ten feet, outcrops near water level in the southeast quarter of section 15, the southwest quarter of section 11, and the northeast quarter of section 12, all these outcrops being on the east (or south) side of the river in T. 135, R. 105. Where ex-

NORTH DAKOTA GEOLOGICAL SURVEY PLATE XII



The entire thickness of the Upper and Lower Fort Union is not shown, only the coal-bearing portions are included in the section.

Clay, brown, carbonaceous		
Coal, with one-inch clay seam 5 feet 6 inches above bottom	9	8
Sand and clay, to river	43	

This bed again outcrops one and a half miles below here, in section 17. In the southern part of the section seven feet of coal are exposed above water level, but half a mile below this coal bed F disappears below the bed of the river and is not again seen.

The somber beds are well exposed on Bacon creek, near the southern border of Billings county, and the thick bed of coal outcropping on the latter creek occurs in these strata. The coal is exposed at the T Cross ranch, in the southern part of section 20, T. 133, R. 104, where it has a thickness of twenty-eight feet above the creek bed and the total thickness is said to be thirty feet.

About seven miles south of here, on Coyote creek in Bowman county, in section 30, T. 132, R. 104, what is probably the same bed is found. Only twelve feet of coal are exposed at this point, the lower portion being covered by talus and deposit from the creek. Three miles west of the above outcrop a bed five feet six inches thick appears along the creek. The coal bed exposed on Bacon and Coyote creeks lies well toward the top of the somber beds and it is perhaps to be correlated with bed F, but this could not be determined with any degree of certainty.

THE GREAT BEND GROUP.

The coal beds of this group occur along the Little Missouri river from the vicinity Yule to the north line of township 138, one mile above the mouth of Garner creek, although all the beds of the group do not extend the entire distance of nearly thirty miles. They are also found on Deep, Sand, Bullion and other creeks emptying into the river along this portion of its course. This group of beds lies in the lower 150 feet of the light colored, middle, division of the Fort Union, and just above the somber beds which contain the Yule group.

Two miles east of Yule, on the east side of the river, in sections 21 and 28, T. 136, R. 104, two thick beds of coal occur in the upper strata exposed here, the section being as follows:

	Feet	Inches
Bed I: Coal at 200 feet above river	8 to 10	
Shale and sandstone	35 to 40	
Bed H: Coal	5½ to 7	
Shale and sandstone, to river	160	

The lower of these two beds, H, outcrops below here in the northeast quarter of section 17, and the northeast quarter of section 9, of the same township and range. Several miles farther down the river, on the north side, in the northeast quarter of section 1, T. 136, R. 104, the following beds are exposed:

		Feet	Inches
Bed I	Coal		8
	Clay	1	4
	Coal	2	4
	Clay	3	
	Coal	1	
Shale and sandstone		35	
Bed H: Coal		5	6
Shale and sandstone		70	
Bed G: Coal, overlain by brown clay		4	6

The two upper beds, H and I, appear again in section 5, T. 136, R. 103, where the upper is five feet thick and the lower six and a half feet. All three beds of this group are exposed in the bluff on the north side of the river in section 3, T. 136, R. 103, across from the J. H. Follis ranch. The section here is as follows:

	Feet	Inches
Bed I: Coal	8	8
Shale and sandstone	10	
Bed H: Coal	5	2
Shale and sandstone	55	
Bed G: Coal	5	6
Shale and sandstone	80	

These beds are again exposed three miles below, in the east half of section 1, T. 136, R. 103, where, across from the Tyler ranch, the following section is well shown:

	Feet	Inches
Shale and sandstone	25	
Coal	1	6
Shale	2	
Bed I: Coal	11	6
Shale	4	6
Bed H: Coal	5	4
Sandstone	7	8
Coal	1	2
Shale	7	6
Bed G: Coal	6	10
Unexposed to river, about	70	

One-half mile north of this section and on the opposite side of the river only two coal beds occur, beds H and I having apparently become one by the thinning out of the intervening clay. The section here, near the north line of section 1, T. 136, R. 103, is as follows:

	Feet	Inches
Coal	2	
Shale and sandstone	20	
Beds H and I: Coal	17	6
Clay	1	
Coal	1	3
Clay	3	5
Coal		2
Clay	4	9
Coal		3
Clay		20
Coal		8
Clay, brown, carbonaceous		27
Bed G: Coal	5	6
Shale and sandstone, to river	35	

One mile southeast, in the southwest quarter of section 6, T. 136, R. 102, the three coal beds are present, though the upper one, I, has been burned out in the face of the bluff. The section here is:

	Feet	Inches
Clinker formed by burning of coal bed I		
Shale, buff	30	
Bed H: Coal	5	6
Shale	10	
Bed G: Coal	7	8
Shale and sandstone, to river	75	

One mile east, in the lower part of the Tepee Butte section, given on a previous page, the three coal beds each contain clay seams as shown in the following section:

		Feet	Inches
Bed I	Coal	1	4
	Clay		3
	Coal		6
	Clay		6
	Coal	9	4
Sandstone and shale		31	
Bed H	Coal	2	2
	Clay		2
	Coal	2	8
Sandstone and shale		22	
Bed G	Coal		10
	Clay		6
	Coal	1	6
	Clay		2
	Coal	3	2
	Clay		1
	Coal	1	8
Shale and sandstone, to river		85	

A little over one and a half miles southeast of the above section, in the southwest quarter of section 9, T. 136, R. 102, and opposite the mouth of Sand creek, only the two upper coal beds appear. While the lower bed, G, may be present, it does not outcrop, since the strata forming the lower part of the bluff are largely unexposed.

	Feet	Inches
Bed I: Coal with 9-inch seam 5 feet above base..	21	6
Shale	22	
Bed H: Coal, with 3-inch clay parting 13 inches below top	6	10
Shale and sand, mostly unexposed, to river	105	

It will be seen from the foregoing sections that there are three workable coal beds outcropping in the bluffs of the Little Missouri river for ten miles above the mouth of Sand creek, the upper (I) being the thickest and varying from nine to twenty-one feet.

Bed H is exposed two and one-half miles below the mouth of Sand creek, in the northwest corner of section 11, T. 136, R. 102. The upper bed, I, is here represented by a layer of clinker formed by its burning, and fourteen feet below is the bed H, which shows the following section:

	Feet	Inches
Coal with 2-inch clay parting 2 feet below top	7	4
Clay	2	4
Coal		9
Clay	3	3
Coal	3	2
Clay		2
Coal	1	9

In section 2, about one-half mile below, in the bluff of the Little Missouri, the upper coal bed, I, lies 135 feet above the river and measures 11 feet 4 inches in thickness, while forty feet below is the bed H, which is 5 feet 4 inches thick. These same beds appear in the following section, which is found on the west side of the valley in the northeast quarter of section 36, T. 137, R. 102:

	Feet	Inches
Sandstone, fine-grained, argillaceous, to top of bluff.	20	
Coal	3	4
Sandstone, fine-grained, argillaceous	7	7
Clay	1	
Coal		1
Clay, gray		18

		Feet	Inches
	Coal		3
Clay		3	1
Bed I	Coal		14
	Clay		3-4
	Coal	10	6
	Clay		2
	Coal	5	1
Shale		33	
Bed H:	Coal	3	8
Unexposed to river		24	

Coal bed H does not appear in the bluffs of the Little Missouri below this point, since the dip of the strata carries it below river level, and only one thick bed of coal (I) is present. But the beds of this group occur on Third, Second and Sand creeks, where there are many outcrops.

All three beds of the Great Bend group appear on Third creek. The presence of the upper bed, I, is made known largely by the layer of clinker formed by its burning along the outcrop, this clinker horizon being traceable for many miles up the creek. The middle bed, H, outcrops in sections 33 and 35, T. 137, R. 101. In the former locality the section of the bed is as follows:

	Feet	Inches
Coal	6	
Clay	6½	
Coal	7	

In section 35 the following section is exposed:

	Feet	Inches
Coal	8	3
Clay	2	
Coal	2	

The lower of the three coal beds, G, is well exposed in the cut bank on Third creek, in section 4, T. 136, R. 101, where the following section appears:

	Feet	Inches
Shale	15-50	
Coal	7½-8½	
Shale	8-10	
Coal	10	
Shale	3	
Coal	3	6
Unexposed to creek	7	

The three coal beds in the above section are considered as belonging to a single horizon (G), and they lie from thirty to forty feet below the middle coal bed of the group.

Second creek empties into the Little Missouri river two miles below the mouth of Sand creek and thick beds of coal are well exposed in the valley. In a ravine tributary to the main valley, in the northwest quarter of section 12, T. 136, R. 102, the following section appears:

	Feet	Inches
Bed I: Coal	12	3
Shale	20 to 24	

One-half mile south of here in the southwest quarter of section 12, T. 136, R. 102, at the J. D. Russell ranch, the lower of the beds occurring in the above section is well shown and is here represented by three coal beds, as follows:

		Feet	Inches
Shale		10	
Bed H	Coal, with 2-inch clay parting 5 feet below top	21	8
	Clay	18	
	Coal	3	8
	Clay	11	6
	Coal, exposed above creek	7	

It will be noted that the total thickness of the coal exposed in the above section is 32 feet 4 inches. The twenty-one-foot coal bed outcrops along Second creek for over a mile above this point.

One-half mile east of Mr. Russell's house, in the southeast quarter of section 12, the upper coal bed (I), which is twenty-four feet above that just given, is well shown as follows:

		Feet	Inches
Shale, sandy		10	
Bed I	Coal	7	6
	Clay		3
	Coal	12	
	Clay		6
	Coal		5½
	Clay		5
	Coal	2	10

One and a half miles south of the Russell ranch, at the Geo. Clark ranch on the Dry Fork of Sand creek, in the west half of section 24, T. 136, R. 102, the following section is shown along the creek:

	Feet	Inches
Shale	12	
Coal		7½
Clay	2	
Coal, with 1-inch clay parting 5 feet below top; base of coal is at creek level	12	

Between one and two miles south of here, in the southeast quarter of section 26, T. 136, R. 102, the following section is exposed:

	Feet	Inches
Shale	10-15	
Coal	8	3
Clay	2	4
Coal	10	4
Sandstone	3	
Coal, with 2-inch clay parting	5	4
Shale, exposed to creek bed	6	

These are doubtless the same coal beds as those outcropping at the Clark ranch, except that at the latter place the lower coal does not show above the bed of the creek. At both localities the horizon represented is probably that of bed H. (Plate XIII., Fig. 2.)

About one mile above the mouth of Dry Fork, in the northeast quarter of section 22, T. 136, R. 102, the bed I is exposed in the bluff bordering the valley. It is here 20 feet 3 inches thick and a section of the coal is as follows:

	Feet	Inches
Coal	7	3
Clay		10
Coal	9	10
Clay		4
Coal	2	

This coal is burned out extensively in the vicinity and is represented by a thick layer of clinker. In the northwest quarter of section 22, T. 136, R. 102, at the junction of Dry Fork and Sand creek valleys, the following section occurs:

		Feet	Inches
Clinker layer, formed by burning of coal bed I		10	
Shale, gray, sandy		24	
Shale, brown			16
	Coal	2	4
Bed H	Clay		6
	Coal	2	8
Unexposed to creek		90	

Both the upper and lower coal beds, H and I, appear on the west side of the valley of Sand creek, about three miles above its mouth,

Fig. 1. Coal bed I of the Great Bend group exposed on Little Missouri near the Harmon ranch. Total thickness of coal, sixteen feet.

Fig. 2. Coal beds of the Great Bend group exposed three and a half miles southeast of the mouth of Sand creek. Aggregate thickness of coal, twenty-four feet.

Fig. 1. Coal bed thirty-five feet thick exposed on Sand creek. The lower portion of the bed is covered with talus, but the coal extends from base of picture to the top.

Fig. 2. A distant view of the 35-foot coal bed on Sand creek. Photo by A. L. Fellows.

in the southeast quarter of section 28, T. 136, R. 102. The section is as follows:

	Feet	Inches
Bed I: Coal	20	
Shale	15	
Bed H: Coal	7	8
Unexposed to creek	85	

Following up the valley of Sand creek there are few outcrops of these coal beds until the old Russell ranch is reached, in the northeast quarter of section 31, T. 135, R. 101. Here is exposed the thickest coal bed in North Dakota, so far as known, the section being as follows:

	Feet	Inches
Clay and sand wash	5–10	
Shale (Fort Union)	4–6	
Coal	3–4	
Clay	2½	
Coal	35	
Clay, to creek bed	3	

The 35-foot bed is clean coal throughout, with no clay seams. (Plate XIV., Figs. 1 and 2.) It outcrops again on the creek one-half mile south, near the south line of section 31. This thick bed of coal has burned out extensively and was traced by its clinker horizon for many miles down the valley of Sand creek. There is little doubt that this 35-foot bed is the same as the upper bed (I) that outcrops on the creek seven or eight miles below, in section 28, T. 136, R. 102, where its thickness is twenty feet; or it may be that the upper and lower beds, H and I, occurring in the lower course of Sand creek valley, have come together through the thinning out of the intervening clay, and that the 35-foot bed is formed by the union of beds H and I.

There are several other coal beds in the Sand creek district which are above the three forming the Great Bend group, but which are mentioned here since they cannot be definitely correlated with the higher beds occurring elsewhere in the region.

A coal bed five and a half feet thick outcrops on the creek at Sandcreek Post Office, near the east line of section 34, T. 134, R. 101. The following occur in Black Butte, where they are exposed near the east end, in a ravine in section 19, T. 134, R. 101.

	Feet	Inches
Coal	5	1
Clay	4	5
Coal	3	6
Clay		14
Coal	3	4

This coal is in the upper, dark colored division of the Fort Union.

Returning to the Little Missouri river, we will now trace the coal beds of the Great Bend group down the valley from the mouth of Third creek. At the sharp bend in the southwest quarter of section 19, T. 137, R. 101, near Mr. German's ranch, the upper member of the group, bed I, outcrops fifty feet above river level. It has a thickness here of sixteen feet, is overlain by twenty feet of sandstone, and contains several thin clay seams one or two inches thick. Less than one-half mile northwest of this outcrop the same bed is exposed in a ravine tributary to the river, the thickness of the coal here being 13½ feet, with a 2-inch clay seam 2½ feet above the base. This bed can be traced in the bluffs bordering the west side of the Little Missouri valley, both by its occasional outcrops and by the thick layer of clinker formed where it has burned. At the oxbow bend in section 3, T. 137, R. 102, the coal measures 13 feet and 8 inches and lies 50 feet above the river, and its thickness at the mouth of Bullion creek is ten feet. Between four and five miles below the mouth of Bullion creek in section 18, T. 138, R. 102, the coal bed I is at water level and is 10 feet 4 inches thick. Two miles north of this point the northward dip of the strata carries this thick bed below river level and it does not appear again. Its last outcrop in going down the river is near the north line of section 5, T. 138, R. 102, about three-quarters of a mile above the Harmon ranch. (Plate XIII, Fig. 1.) The section of bed I is here as follows:

	Feet.	Inches.
Shale, buff and gray	10–50	
Shale, carbonaceous, black and brown	5	6
Coal	11	8
Clay		7
Coal		8
Clay		4
Coal, bottom of bed several inches above low water	3	6

Since the bed I is the highest of the Great Bend group, it follows that none of the members of that group is exposed north of the north line of T. 138, although they doubtless extend many miles in

that direction below river level. Bed I outcrops at various points on Bullion creek for five or six miles above its mouth. In the southeast quarter of section 1, T. 137, R. 103, about one mile above its mouth, the coal is ten feet thick; near the east line of section 11 it is nine feet; in section 13, T. 137, R. 104, it is five feet; and at the old Nollet ranch, near the east line of section 10 of the same township and range it has a thickness of five feet and lies 25 feet above the creek. No outcrops of bed I were seen west of this point, unless the coal exposed in the northeast quarter of section 9, and having a thickness of 26 to 30 inches, is this member, which grows thinner toward the west. In the northeast quarter of section 10 a lower coal bed, possibly H, has been mined on a small scale. The coal lies two feet above creek level and a thickness of three feet is exposed, but the base of the bed is not shown. It is overlain by twenty inches of brown, carbonaceous clay.

About one-half mile southeast of Alpha, near the center of section 33, T. 137, R. 104, a coal bed is well exposed on a short tributary of the Little Missouri river. The section is as follows:

	Feet.	Inches.
Clay wash	3–6	
Clay, blue	2	
Clay, brown, carbonaceous		8
Coal	6	6

Considerable coal has been mined here by the farmers of the vicinity, who work it by stripping off the cover. This coal probably belongs to bed H, which appears in the river bluffs several miles to the southeast. The former presence of a higher coal bed (I) in this district is evident from the burnt clay seen at many points.

Coal is also exposed in several places in the vicinity of Burkey, where it outcrops on Bullion creek and its tributaries. In the southeast quarter of section 5, T. 137, R. 105, seven feet of coal outcrops just above creek level, and the bottom of the bed is not exposed. The cover in ten feet thick, increasing in thickness back from the creek. The coal has been mined here for a distance of sixty feet along its outcrop. In the northeast quarter of section 8, what is probably the same bed has been mined at intervals for a distance of 100 feet along the creek. The full thickness could not be determined here, as the bottom of the coal is below the creek bed, but a measurement near by gave a thickness of 7 feet 3 inches. Coal also

outcrops two and a half miles east of Burkey, in the northern half of section 11, T. 137, R. 105, where the following section appears:

	Feet.
Coal	5
Clay	10
Coal, exposed, but not the entire thickness	2½

It is evident from the foregoing detailed description of outcrops that the coal beds of the Great Bend group cover a large area. This is especially apparent in the case of the thicker upper bed, whose outcrops are distributed over a more extensive area than those of the lower members of the group. This bed, I, is known to extend from the southern boundary of T. 135 north twenty-four miles to the northern line of T. 138, and from the eastern edge of R. 101, west twenty-one miles to Yule. It covered an area of at least 500 square miles and undoubtedly much more. It varies in thickness from five feet and less to thirty-five feet.

THE MEDORA GROUP OF COAL BEDS.

The members of this group outcrop along the valley of the Little Missouri river from the vicinity of Bullion Butte northward to the northern boundary of Billings county. The four beds which constitute the group have a vertical range of about 200 feet, the lower member lying some ninety feet above bed I. The two middle beds appear in the river bluffs at Medora, whence the name of the group, and the thicker one is mined at that point. The beds of this division have been designated in the vertical section by the letters J, K, L and M. Not only do these outcrop on the Little Missouri river, but they occur in the northwestern part of the region, on Beaver and Elk creeks, and on Andrews creek near Sentinel Butte station.

For convenience in description we will begin near Medora and trace the beds first south, and then north to the county line.

The following is the section of the coal beds which are present in the bluffs at Medora:

		Feet.	Inches.
Shale			
Bed L:	Coal	4	6
Shale and sandstone		31	
Bed K:	Coal		2
	Clay		2
	Coal	8	
	Clay		3
	Coal		11
Shale and sandstone, to river		40	

The lower coal, K, has been mined here for a number of years. From six to six and a half feet of coal are removed and the remainder is left to form the roof of the mine. The entry of the present mine is about 100 feet long. This same bed was formerly mined extensively by the Northern Pacific Railway Company, their old workings being located on the west side of the river not far from the railroad bridge.

About two miles south of Medora, in the steep bluff at the mouth of Sully creek, the beds K and L are both well shown. The lower (K) is here eighty feet above the river and is 8½ feet thick, while forty feet above is the upper bed (L) with a thickness of five feet.

The lower bed is exposed on Sully creek in the northwest quarter of section 2, T. 139, R. 102, where its thickness is nine feet, and it disappears below creek level near this point. Near the southern edge of section 1, T. 139, R. 102, the two higher beds of the Medora group appear in the side of the creek valley, the section being as follows:

		Feet.	Inches.
Shale and sandstone			
Bed M:	Coal	3	2
	Clay, brown and carbonaceous below	5	6
	Coal	4	4
Sandstone, massive, with some shale above		60	
Bed L: Coal		5	
Clay, to creek bed		10	

The upper coal bed, M, is represented in many places by a single bed.

In the bluff of the Little Missouri river at the Custer Trail ranch, in section 10, T. 139, R. 102, the following exposure occurs:

	Feet.	Inches.
Bed M: Coal		2½
Shale and sandstone	30	
Bed L: Coal	4	
Shale and sandstone	45	
Bed K: Coal	6½	
Unexposed to river	95	

One and a half miles south of here, in the northeast quarter of section 22, three coal beds are exposed in the river bluff, as follows:

		Feet.	Inches.
Bed K:	Coal	1	6
	Clay, brown		6–11
	Coal	6	6
	Clay, brown	1	
	Coal	6	

Shale and sandstone	32	
Bed J: Coal	7	6
Shale and sandstone	21	
Coal	4	
Shale and sandstone, to river	45	

The lowest coal bed of the above section does not appear elsewhere and is probably only a local seam.

Bed K also outcrops in the northeast quarter of section 6, T. 138, R. 102, where it lies at an elevation of 125 feet above the river and is seven feet thick. About thirty-five feet above K is a bed three to four feet thick which is probably L. No more outcrops of these beds were observed in going up the river until Bullion Butte was reached. Here, in a ravine on the north slope, in section 12, T. 137, R. 103, the following coal bed is exposed:

	Feet.	Inches.
Coal	4	4
Clay	4	
Coal	3	10

This coal lies about 180 feet above the river and probably is to be correlated with bed K of the Medora group. Five miles to the east, in the southwest quarter of section 2, T. 137, R. 102, what is doubtless the same bed occurs in the river bluff. It has a thickness of six to eight feet and is 200 feet above water level. In the divide south of Bullion creek, between the latter and the Little Missouri, there is a coal bed five feet thick which belongs to the same group. South of Bullion Butte and of the high divide just mentioned the members of the Medora group do not occur, since the surface of the plain is below their horizon.

North of Medora these beds outcrop at frequent intervals for many miles along the valley of the Little Missouri. They are well exposed where the river swings against the bluff near the center of section 15, about two miles north of the railroad. Here the bed K is six to eight feet in thickness and lies fifty feet above the river, while thirty feet higher is the coal bed L with thickness of four feet. The two beds approach each other toward the north and northeast, and in the bluff in the northeast quarter of section 10 they are not over twelve feet apart. The lower outcrops on Knutson creek for about two miles above its mouth, measuring 7½ feet in thickness. Both are well exposed on the river in the northeast corner of section 11, across from the Burgess ranch, where the following section is well shown:

Coal beds of the Medora group exposed on Little Missouri river near the mouth of Ash creek. Total thickness of coal, sixteen feet and five inches.

	Feet.
Bed L: Coal	4½
Shale and sandstone	11
Bed K: Coal exposed above water level of the river, but extends below this	8

These two beds outcrop across the river, in a cut bank on Paddock creek, in the northwest quarter of section 12, where only the upper foot or two of the lower coal is exposed, overlain by 12 feet of sandstone and clay and the 5-foot upper coal bed.

A short distance below the outcrop across from the Burgess ranch the two beds of coal dip below river level, but reappear again about two miles to the north, in the northeast quarter of section 32, T. 141, R. 101. Here, in the cut bank on the west side of the river, the following section appears:

	Feet.	Inches.
Clay		
Coal		2–4
Clay	1½–2	
Bed L: Coal	4½–5	
Sandstone, firmly laminated, passing below into clay	8–10	
Bed K: Coal, only the upper part of the bed is shown here, and exposed thickness is	2	

For over ten miles north of this exposure these two beds are below the river, and no workable coal is present in the bluffs of the Little Missouri, but the beds K and L are probably not far below the bottom of the valley, for they again appear farther down stream.

In the southwest quarter of section 11, T. 142, R. 102, the following section is well exposed in the steep cut bank on the east side of the river:

	Feet.	Inches.
Clay wash	4–6	
Clay, sandy	6–8	
Coal	1	
Clay	5	6
Coal	3	
Clay, sandy	6	
Bed K: Coal	6	
Bed K: Clay, sandy	3	6
Bed K: Coal	6	5
Clay exposed above river	1	

Total thickness of coal, 16 feet 5 inches. (Plate XV.)

Three miles below, in the northern half of section 35, T. 143, R. 102, a coal bed sixteen feet thick outcrops on the river. (Plate

XVI., Fig. 1.) Less than one mile below, in the southeast quarter of section 27, T. 143, R. 102, the following section is well shown:

	Feet.	Inches.
Sandstone, fine-grained, gray and buff	10	
Sandstone, argillaceous, fine-grained and finely laminated, contains many iron pyrites nodules	2	6
Bed L: Coal	2	10
Clay		10
Bed K: Coal	3	4
Bed K: Clay		10
Bed K: Coal	7	7
Sandstone, argillaceous, fine-grained and laminated, contains many iron pyrites nodules and some carbonized roots running down from coal, exposed above river	4–5	

The three coal beds of the above section probably represent, as indicated, K and L, the clay separating the upper and lower coal having thinned to only ten inches and the lower bed (K) being divided by a ten-inch clay band.

In the extreme northeast corner of section 21, T. 143, R. 102, less than two miles below the last-mentioned outcrop, the same beds are exposed in the river bluff, and a lower bed of coal appears, the section being as follows:

	Feet.	Inches.
Sandstone		
Bed L: Coal		31
Clay		10
Bed K: Coal	3	2
Bed K: Clay		8
Bed K: Coal	6	8
Sandstone, argillaceous, fine-grained	40	
Bed J: Coal, partly under water	3½–4	

The lower bed, J, is a lower coal which does not appear along the Little Missouri between Medora and this point, but which was traced from here to the mouth of Beaver creek.

Continuing down the river one mile another good exposure of the coal beds is found in the steep bluff on the east side of the river near the west line of section 15, T. 143, R. 102 (Plate XVI., Fig. 2), the section being as follows:

	Feet.	Inches.
Shale and sandstone		
Bed K and L: Coal, with three clay partings 1 to 3 inches thick in upper half of the bed	10	
Sandstone and shale	30	
Bed J: Coal		32–34
Clay, exposed to water level	2–6	

Fig. 1. Coal bed sixteen feet thick, two miles southeast of mouth of Roosevelt creek, in section 35, T. 143, R. 102.

Fig. 2. Two coal beds about one mile below the mouth of Roosevelt creek, in section 15, T. 143, R. 102. The upper bed is ten feet thick.

The coal beds K and L, which have been approaching each other through the thinning of the intervening clay, here unite to form one thick bed with, however, several clay partings, which farther north thicken in places and split the coal into several seams. This is well shown in the northeast corner of section 17, T. 143, R. 102, where the same coal beds are well exposed, as follows:

		Feet.	Inches.
Sandstone, argillaceous		12	
Clay		3	
Bed K and L:	Coal	2	
	Clay		4
	Coal		8
	Clay		1
	Coal	2	
	Clay		7
	Coal	5	6
Sandstone, massive, with some clay		30	
Bed J: Coal			32
Sandstone and shale, to river level		30	

The upper coal with three clay seams corresponds to the ten-foot bed of the preceding section formed by the union of K and L.

This same upper coal horizon outcrops in the river bluffs two miles to the north in the southwest quarter of section 33, T. 144, R. 102, across the river from Roosevelt's old Elkhorn ranch, the section here being as follows:

		Feet.	Inches.
Clay			
Coal			8
Clay		1	
Bed L: Coal		4	
Sandstone		5	6
Bed K:	Coal		8
	Clay	3	6
	Coal	1	
	Clay	1	6
	Coal	4	
Unexposed to river, about		50	

The lower bed is not exposed at this point.

The splitting up of the coal into many beds by clay seams is well illustrated in this section. There is no doubt that this is the same horizon which both to the north and south of here is represented by a single thick bed of coal.

Less than one and a half miles below the above outcrop, in the west half of section 27, T. 144, R. 102, the following section occurs:

		Feet.	Inches.
Sandstone, massive			
Bed K and L:	Coal	1	
	Clay		8
	Coal	3	
	Clay		15–40
	Coal		15
Sandstone and clay; sandstone massive, fine-grained and laminated		27	
Coal			6
Sandstone		3	
Bed J:	Coal		10
	Clay		8
	Coal, bottom of bed at river level	5	

The rapid variation in the thickness of the clay seams is well shown in this exposure, where within a distance of a few hundred feet the lower clay in the upper coal varies from fifteen to forty inches.

About three miles to the north, in the southeast quarter of section 9, T. 144, R. 102, the same two beds of coal appear as in the following section:

		Feet.	Inches.
Shale and sandstone, to top of bluff			
Coal			26
Shale and sandstone with several thin coal seams, 1 to 3 inches thick		27	
Sandstone ledge		4–5	
Clay, sandy, with thin coal seam		2	
Bed K and L:	Coal	5	8
	Clay		6–10
	Coal	1	
Shale and sandstone		25	
Bed J: Coal		3	2
Clay, to water level			20

These coal beds outcrop again on the west side of the valley, about one quarter of a mile south of the mouth of Beaver creek, in section 6, T. 144, R. 102. (Plate XVII., Fig. 2.) Here in the bluff of the river the following section is exposed:

		Feet.	Inches.
Shale and sandstone to top of bluff with several thin coal seams, about		150	
Bed K and L:	Coal	7	10
	Clay, passing above into coal	6	6
	Coal		13–15
Shale		15	
Coal			10–12
Clay, blue			20
Sandstone, fine-grained		10	
Bed J: Coal			38–40
Shale, to river bed		14	1

Fig. 1. Many thin beds of coal exposed in the bluffs of the Little Missouri several miles above the mouth of Ash creek.

Fig. 2. Coal beds of the Medora group exposed on Little Missouri river just above the mouth of Beaver creek. Upper coal bed eight feet thick.

Coal on Beaver Creek. The two thick coal beds of the above section were traced up the valley of Beaver creek for a distance of four or five miles. They are exposed one mile above the mouth, in the southwest quarter of section 34, T. 145, R. 102, McKenzie county, where the following section appears:

	Feet.	Inches.
Sandstone	10	
Bed K-L: Coal	6	7
Sandstone and shale	43	
Bed J: Coal		35
Shale	8	
Sandstone, to creek bed	21	

Three miles above the mouth of Beaver creek, in the southwest quarter of section 2, T. 144, R. 103, there are several cut banks along the stream where the beds are well shown, as in the following section:

	Feet.	Inches
Sandstone and shale to top of bluff	35	
Coal		20–24
Shale	18	6
Shale, brown, carbonaceous		3
Shale and sand	32	6
Bed L: Coal	4	8
Shale	4	8
Bed K: Coal	3	4
Shale, passing into sandstone above	5	2
Coal		15
Shale, blue	6	6
Shale, black, carbonaceous		0
Coal		3
Shale, sandy	8	
Coal		8
Sandstone	15	6
Bed J: Coal	3	5
Clay, to creek bed	1–2	

Beds K and L undoubtedly represent the single thick upper coal bed appearing on the creek two miles below and also at many points in the bluffs of the Little Missouri. The three thick coal beds of the above section also outcrop about one mile to the southwest, near the south line of section 10, where the lower coal (J) has a thickness of four feet. (Plate XIX., Fig. 1.) The exposure of the beds in a bluff on the creek near the north line of section 22, T. 144, R. 103, is as follows:

	Feet.	Inches.
Sandstone, massive	65	
Bed L: Coal	2	3
Clay	1	6
Bed K: Coal	2	4
Clay, blue	3	2
Clay, black, carbonaceous		8–10
Coal		4
Sandstone, passing above into shale	7	2
Coal	1	6
Clay	8	
Coal		2
Clay	1	
Bed J: Coal	5	6
Clay		10
Coal		8
Clay, to creek level	1	

It will be noted that the lower coal bed (J) has thickened toward the south from 3 feet 5 inches in section 2 to 5½ feet two miles distant. It does not outcrop on Beaver creek above this point but passes below the bottom of the valley, the rise of the surface carrying it above the horizon of this bed. On the other hand, the beds K and L have become thinner toward the south and the thinning of the intervening clay has brought them closer together.

The section of the strata in the high bluffs near the south line of section 22 shows a succession of beds quite different from anything seen below this point on Beaver creek. It is as follows:

	Feet.	Inches.
Coal	1	8
Sandstone	10	
Clay, black and carbonaceous below, sandy above	5	
Coal		3
Clay, carbonaceous at bottom	2	
Coal		8
Sandstone, stained with iron, with some shale	20	4
Coal	2	
Shale	7	
Coal	1	3
Clay	2	6
Coal, impure, clayey	1	8
Shale, sandy	18	8
Bed M: Coal	4	
Clay	4	3
Coal, impure		2
Shale, sandy, carbonaceous layer 4 inches thick near		

Fig. 1. Three coal beds of the Medora group which outcrop on Beaver creek in section 10, T. 144, R. 103. Aggregate thickness of upper two beds is eight feet.

Fig. 2. Bluff on Beaver creek, in section 22, T. 144, R. 103, showing ten coal beds. The thickest coal bed measures four feet and four inches.

	Feet.	Inches.
middle	8	
Coal	2	10
Clay	4	6
Coal	2	4
Sandstone and shale	9	6
Coal	1	6
Sandstone and shale	17	4
Bed K-L: Coal	4	4
Clay		6
Coal		6
Clay, sandy	2	3
Coal		10
Clay and sandstone	6	
Coal		8
Clay and sandstone to creek level	16	

It will be noted in the above section that there are fifteen coal beds outcropping in this bluff and ten of them appear in the accompanying picture. (Plate XIX., Fig. 2.) There are only two, however, beds K-L and M, which are of workable thickness. Of these two, the lower is believed to represent the beds K and L, it having been found that in places these approach each other and even unite to form a single bed. The upper of the two thick beds corresponds in position to the uppermost of the Medora group and is probably to be correlated with coal bed M. The two thick beds shown in the above section and the three thinner ones between them outcrop above here at frequent intervals for a distance of about six miles in the bluffs bordering Beaver creek.

They are well shown in the southeast quarter of section 32, T. 144, R. 103, near the Moore ranch, where the following beds occur:

	Feet.	Inches.
Sandstone	4	3
Coal	1	3
Shale and sandstone	14	
Coal	..	4
Sandstone, argillaceous	6	
Clay, black, carbonaceous	..	4
Clay	5	6
Coal	..	8
Clay, sandy	5	
Bed M: Coal	5	2
Sandstone and shale	16	
Coal	1	4
Sandstone and a little shale	21	

	Feet.	Inches.
Coal	.2	
Sandstone	5	10
Coal	2	
Shale	6	
Coal	..	2
Shale	9	
Bed K-L: Coal, base at creek level	5	8

The lower coal bed (K-L) outcrops on the creek in the northwest corner of section 6, T. 143, R. 103, where the base of the coal is below the bed of the creek, but it is not exposed along the valley above this point, since the coal passes below the bottom of the valley. But the uppermost member of the Medora group (M) is seen in the bluffs bordering the valley of Beaver creek as far as the McQuillon ranch, in section 20, T. 143, R. 104. It will be mentioned again in connection with sections showing the coal beds of the Beaver Creek group.

In the valley of Elk creek, a tributary of Beaver which enters it from the south in the southwest quarter of section 11, T. 143, R. 104, only one workable coal bed is exposed. This is probably the one that appear fifty feet above creek level at the junction of Beaver and Elk creeks, and in that case is the upper member of the Medora group, or bed M. It outcrops in the northwest quarter of section 1, T. 142, R. 104, where the following section occurs:

	Feet	Inches
Sandstone, massive, to top of bluff	20	
Coal		8
Clay, blue		8
Bed M: Coal	4	6
Clay		6
Coal		4
Sandstone and shale above creek bed	25	

Where the coal bed M outcrops in the northwest quarter of section 14, T. 142, R. 104, it is six feet thick and one mile west it measures five feet ten inches. It is this bed which is mined near the old T D (now the Wilson) ranch, the mine being in the northwest quarter of section 21, T. 142, R. 104. The base of the coal does not show here, but it is at least five feet thick. The mine is in the bottom of the valley of Elk creek and the coal is obtained by stripping off the cover, which is here only a few feet thick.

Near the J. B. Bird ranch on Wannigan creek, in section 34, T. 142, R. 103, a bed of coal 3 feet 9 inches thick is exposed. This is probably bed M.

The upper coal bed of the Medora group, M, also outcrops on Andrews creek at several points between two and three miles east of Sentinel Butte. In the southwest quarter of section 21, T. 140, R. 104, the section is as follows:

	Feet	Inches
Sandstone, soft, yellowish	20	
Coal	5	.2
Clay	5	6
Coal	1	
Clay	5	6
Coal	1	6

The coal is mined here on a small scale during the winter for local use. A little over one mile below here, in the southeast quarter of section 22, T. 140, R. 104, there is another exposure of the same bed as follows:

	Feet	Inches
Clay	6	
Coal	1	6
Clay, bituminous		4
Coal	5	

Summarizing the data of the foregoing sections it is seen that the two middle beds of the Medora group, K and L, are 45 feet apart near the Custer Trail ranch, and the lower of the two is about 100 feet above the Little Missouri. They dip to the north and are carried below river bed level a few miles beyond the Burgess ranch. They also approach each other in the same direction, being 35 feet apart at Medora and only eight feet apart opposite the mouth of Jewell creek. Then for nearly ten miles these coal beds are below the river and do not reappear until near the mouth of Ash creek. The three beds exposed here are believed to represent K and L, and the thick upper coal bed occurring in the river bluffs between Ash creek and the northern boundary of Billings county, sometimes split into several by clay seams and sometimes forming a single bed with no partings, is undoubtedly the same horizon. Near the mouth of Roosevelt creek a lower coal bed, J, appears and continues above river level to the mouth of Beaver creek and beyond.

It will thus be seen that from near the Custer Trail ranch to the northern limits of the area two workable coal beds of the Medora

group are present in the bluffs bordering the Little Missouri, the only place where they are below water level being the ten miles between Jewell and Ash creeks.

All four members of the Medora group occur on Beaver creek, but they disappear successively below the bottom of the valley, bed K and L near the south line of T. 144, R. 103, and bed M continuing to within six miles of the Montana line. The latter coal bed also appears on Elk creek as far up as the Wilson ranch.

BEAVER CREEK GROUP OF COAL BEDS.

The coal beds of this group are exposed in the northwestern corner of Billings county, along the valley of Beaver creek and its tributaries. They lie above the beds of the Medora group and the uppermost member is about 100 feet below the Sentinel Butte group. No workable beds of coal at this horizon were found elsewhere in the area under discussion.

In following up the valley of Beaver creek the lowest member of the group, N, first appears near the Keen ranch, in the northeast quarter of section 2, T. 143, R. 104, where the following succession of strata is exposed:

	Feet	Inches
Bed N: Coal	5	
Shale and sandstone	42	
Bed M: Coal	2	9
Shale	8	
Coal		13
Shale	10	
Sandstone, to creek bed	31	

The bed M is without question the upper of the two workable beds exposed on the creek for many miles below, since it was traced almost continuously by its outcrop or the burned clay bed formed by its burning. The five-foot bed of the above section therefore lies over forty feet above the uppermost coal of the Medora group.

The beds M and N of the above section are seen at many points in the bluffs bordering the valley between the Keen ranch and the mouth of Elk creek. At the junction of Elk and Beaver creeks the following section is well shown, in section 11, T. 143, R. 104.

		Feet	Inches
Shale and sandstone, to top of bluff			
Bed N	Coal	3	
	Clay	2	
	Coal	1	6
Shale and sandstone, not well exposed		42	

		Feet.	Inches.
Bed M	Coal	3	6
	Clay	3	
	Coal	2	
Shale and sandstone		30	
Coal		3	10
Shale, to creek bed		16	

Bed N has burned out extensively and the clinker layer formed by it shows in many places along the valley. The bed sixteen feet above the base of the section appears to be one which is not exposed elsewhere, unless it be the same coal which outcrops about five miles above, near the McQuillon ranch.

On Beaver creek about three miles above the mouth of Elk creek, the following section is exposed in the northwest corner of section 21, T. 143, R. 104:

	Feet	Inches
Bed O: Coal	6	6
Shale and sandstone	14	
Bed N: Coal	2	4
Shale	7	
Coal	2	2
Unexposed	46	
Bed M: Coal	4	
Unexposed to creek	50	

It will be noticed in the above section that a workable bed, O, is here present above coal N, and for eight or ten miles below the McQuillon ranch this has a uniform thickness of 6½ feet and is the thickest bed appearing in the bluffs of Beaver creek valley. It it the middle bed, O, of the Beaver Creek group.

A little over a mile west of the above section the following beds appear in a steep bluff rising from the creek, in the northeast quarter of section 19, T. 143, R. 104:

		Feet	Inches
Sandstone to top of bluff		12	
Bed O: Coal, with 3-inch seam 18 inches above base		6	6
Shale and sandstone		15	6
Coal		2	
Shale		10	6
Bed N	Coal		20
	Clay	3	10
	Coal	2	2
Shale and sandstone		37	
Bed M: Coal		3	8

	Feet.	Inches.
Shale and sandstone	21	
Coal	2	10
Unexposed to creek bed	14	

The lowest bed in the above section is probably the same as the lower one exposed at the mouth of Elk creek.

About four miles above the last section, in the northeast quarter of section 26, T. 143, R. 105, the coal bed O is again exposed, the outcrop here being as follows:

	Feet	Inches
Bed O: Coal	6	6
Shale and sandstone	37	
Coal	3	
Shale	8	
Coal		26
Shale	4	
Coal, with 2-inch clay seam near top		29
Unexposed to creek	44	

The most westerly outcrop visited on Beaver creek was in the northwest quarter of section 34, T. 143, R. 105, three miles from the Montana line. In a steep bluff the following section is exposed here:

	Feet	Inches
Sandstone and shale to top of bluff	20	
Bed O: Coal	6	6.
Sandstone and shale	22	
Coal	3	
Sandstone	10	
Coal	2	6
Shale and sandstone	36	
Coal	4	
Sandstone, exposed above creek	40	

Four beds of coal are exposed in the sides of the valley of the tributary of Beaver creek which flows through T. 142, R. 105. The thickest of these is the 6½-foot coal O, and sixty-five feet above is the upper bed of the Beaver Creek group, the bed P, which has a thickness of four feet.

It will be seen from the foregoing sections that the Beaver Creek group includes three coal beds. The lower, N, is exposed along the creek in T. 143, R. 104, and has a maximum thickness of five feet near the Keen ranch in section 2. Above here it is separated by a clay seam into two coal beds. The middle bed, O, has a uniform thickness of 6½ feet and lies about fifteen feet above N, outcrop-

ping along the creek from the McQuillon ranch in section 20, T. 143, R. 104, almost if not quite to the Montana line. The upper bed, P, has a thickness of four feet and was only seen at one point several miles south of Beaver creek.

The three coal beds occurring below bed O, above the McQuillon ranch, are so variable and unlike those farther down the creek that they cannot be correlated with any certainty with those found elsewhere.

The beds of this group undoubtedly extend back from Beaver creek for some miles to the north and south and should be struck in boring wells or in prospect holes.

Two beds of workable thickness are present on Little Beaver creek, in T. 141, R. 105. The outcrop of one of these disappears below the level of the creek about one-half mile east of the Montana line, where it is six feet thick.

The coal bed mined in the northwest quarter of section 8, T. 141, R. 105, shows the following section:

	Feet	Inches
Coal	6	6
Shale, sandy	8	
Coal	3	

The same bed is mined in the northwest quarter of section 16, T. 141, R. 105, where the following section appears:

	Feet	Inches
Coal	2	2
Clay		6
Coal		5
Clay		6
Coal	5	6

SENTINEL BUTTE GROUP OF COAL BEDS.

The coal beds of this group are the highest in the region and are thus named from the fact that at least three of the members are present in Sentinel Butte. Five coal beds are included in this division and they have a vertical range of about 300 feet. The four upper beds are in the dark strata forming the upper division of the Fort Union, while the lowest member lies forty to fifty feet below the contact of the two divisions. The coal beds of the Sentinel Butte group extend from Bullion Butte and the divide between Third and Bear creeks on the south to the divide north of Ash creek on the north, a distance of 35 miles; they extend from Sentinel Butte on the west to the divide near Fryburg on the east, a distance

of 25 miles, and how much farther east they occur was not determined. These coal beds have been extensively eroded over wide areas and they have also burned out on a very large scale. The bed which lies at the base of the upper Fort Union, R, can be readily traced by its red clinker horizon in the bluffs and ridges of the Little Missouri badlands as far as the eye can see.

The outcrops of the Sentinel Butte group south of the Northern Pacific railroad will first be discussed and later those north of the track will be considered.

Three of the coal beds of this group occur in Bullion Butte, that portion of the section containing them being as follows:

	Feet	Inches
Bed S: Coal	3	3
Shale, sandy, dark gray, contains near base many ferruginous nodules	50	
Bed R: Coal, at contact of upper and lower divisions of Fort Union	15	
Shale and sandstone	40	
Bed Q: Coal, at elevation of about 360 feet above river	5	

Coal bed R outcrops in the southeast quarter of section 12, T. 137, R. 103, near the north end of the butte, and it is also exposed near the south end in sections 29 and 30 of T. 137, R. 102. In this latter locality the coal measures 6½ feet thick and contains a three-inch clay seam two feet above the bottom. This thick coal bed undoubtedly underlies the entire butte.

About four miles southeast of Bullion Butte two very conspicuous elevations rise above the nearly vertical bluff of the Little Missouri and in these Tepee Buttes, as they are called, three high coal beds of the Sentinel Butte group occur. The detailed section of the strata at this point has been given on a previous page and only the upper part showing the coal is contained in the following section:

	Feet	Inches
Sandstone and shale to top of Teepee Buttes	52	
Bed T: Coal	4	6
Shale and sandstone	95	
Bed S: Coal	6	3
Shale and sandstone	25	
Bed R: Coal, with 2-inch clay seam two feet above bottom. Bed 400 feet above river	5	2

The lowest coal bed, Q, of this group occurs in the high divide west of Bullion Butte, between Bullion creek and the river, which

here has an easterly course. This coal lies about fifty feet below the coal bed R, and is therefore in the buff, light colored division of the Fort Union. It lies at an elevation of about 320 feet above the river and has a thickness of ten feet. It is exposed in the southeast quarter of section 28, T. 137, R. 103, and at other points in the divide. No measurement was secured on this divide of the coal bed R, at the contact of the two divisions of the Fort Union, as it has burned out over a large area and its outcrop is marked by a thick layer of clinker.

The beds of the Sentinel Butte group are known to extend at least eight miles east of the Little Missouri and probably continue considerably farther in that direction. The beds Q and R occur in the higher ridges and divides between Third and Bear creeks, in T. 137, R. 101. The coal R near the center of this township is nine feet thick and the lower bed Q, is here only fifteen feet below and is 5½ feet thick. The former bed, R, was traced by its clinker horizon several miles east of the above township, or as far as the divide between the drainage of the Little Missouri and Missouri rivers.

The lower bed, Q, is exposed on Bear creek in the southeast quarter of section 36, T. 138, R. 102, where it measures 4 feet 4 inches in thickness and lies just above creek level. The bed R outcrops for some distance along the creek three miles above here, near the southwest corner of section 34, T. 138, R. 101. The section of the coal bed is as follows:

	Feet	Inches
Coal	6	2
Clay		14
Coal		20

This is one of the few places where this bed of coal contains a clay seam, and it is generally free from clay partings. Mr. Schuyler Lebo, who has a detailed and accurate knowledge of township 138, ranges 101 and 102, states that the coal bed R outcrops in the following sections: 12, 14, 26 of T. 138, R. 102, and in 8, 10, 21 of T. 138, R. 101. This thick bed of coal underlies practically all of the latter township, except where it has been cut out by the streams. A measurement of this same bed was secured in the southeast quarter of section 23, T. 139, R. 102, where the coal is exposed near the top of the bluff at an elevation of 280 feet above the river. It here has a thickness of seventeen feet and is overlain by fifteen to twenty feet of clay.

Along the valley of Sully creek the bed R has burned out extensively and along either side of the valley its horizon is marked by a thick layer of clinker which forms a very conspicuous scenic feature of this region. This bed of coal disappears below the bottom of the valley about one-half mile east of Sully Springs. The burnt clay so abundant along the Northern Pacific railroad in the vicinity of Scoria was largely formed by the burning of this coal, although there is a higher bed which has formed some clinker. The so-called burning mine, about one-half mile south of Sully Springs, is in this same coal bed, which has been burning for many years. (Plate XI.) The only place on Sully creek where an outcrop of the coal R was found was in the west half of section 14, about one mile from the above station; the upper part of the coal is here burned and has also been eroded, so that the full thickness could not be obtained, but seven feet of coal remain. Layers of clinker indicate that there are in this vicinity two coal beds above this one. One is 150 feet and the other 240 feet above the bed R, and it is quite likely that they are to be correlated with the two higher coal beds occurring in Sentinel Butte, at the same relative distances above the coal R. No outcrops were found on Sully creek where the thickness of these upper coal beds could be measured.

West of the Little Missouri river two members of the Sentinel Butte group are present in the base of Square Butte. The lower of the two, R, is five feet thick, and twenty-five feet above, separated by sandy shale, is the upper bed, S, with a thickness of fifteen feet. This latter bed is exposed in the northeast quarter of section 9, T. 139, R. 103. East of the river this upper thick bed does not occur on Sully creek or to the south of that stream.

Between Flat Top and Sentinel buttes there is a conspicuous clinker layer formed by the burning of coal bed S. About midway between the two buttes the lower bed, R, outcrops, with a thickness of five feet, and lies 50 feet below the clinker layer.

In Sentinel Butte the three upper members of this group are present. The lower of them outcrops at several points toward the bottom where it has been mined in the northeastern base, in southeast quarter of section 5, T. 139, R. 104, and the section of the bed S is as follows:

	Feet	Inches
Clay, sandy		
Coal	14	
Clay		3
Coal	6	11

This same bed has been mined in the northwest quarter of section 7, where it is 20 feet 11 inches thick. It has also been mined in the southwest quarter of section 5, and on the south and west sides of the butte. Ninety feet above this thick one is a six-foot bed of coal. The highest member is known to occur by its clinker and no exposure was seen.

A few small areas underlain by beds R and S occur in the southeastern corner of T. 139, R. 105, where they have escaped the erosion which has removed them from much of the region. Near the center of section 25 coal has been mined by stripping, the section here being as follows:

	Feet	Inches
Clay, white		
Coal	8	
Clay		10
Coal, base not exposed	7	

This bed also occurs in the base of Rocky Butte, in section 34, but it is concealed by clinker so that its thickness could not be determined.

The bed S is present in the base of Camels Hump Butte, in sections 9 and 10, T. 140, R. 104, but the coal has burned out along its outcrop and is concealed by clinker, so that no exposure could be found.

In the divide north of Andrews creek, the two beds R and S of the Sentinel Butte group occur. Near the western edge of T. 140, R. 103, they are separated by 55 feet of the dark gray strata of the upper division and each measures 5½ feet in thickness. Both the beds are extensively burned.

In section 35 of T. 141, R. 102, bed R outcrops at an elevation of 250 feet above the Little Missouri river, but only the upper 6½ feet of coal is exposed to view.

The same coal bed, R, underlies the irregular plateau in sections 8, 9, 10, 16 and 17, T. 140, R. 102, at an elevation of about 275 feet above the Little Missouri river. Its outcrop is nearly everywhere concealed by clinker so that its thickness could not be determined.

In the divide between Government and Franks creeks, in T. 141, R. 101, the bed R occurs at the contact of the dark-colored strata with the buff and light gray beds below. It lies from 250 to 300 feet above the Little Missouri river and is found in the buttes which rise above the general level of the divide. In the southwest quarter of section 5 the coal is 11 feet 6 inches thick, with a 3-inch clay parting

6 inches from the bottom. In the southeast quarter of section 12 that portion of the bed which is exposed measures 16 feet and the entire thickness is probably not much more than this. The bed R is also found in the divide between Franks and Ash creeks, though it is not well exposed in that area, but north of Ash creek the coal grows thin and partings develop in the bed. Thus in the northeast quarter of section 4, T. 142, R. 101, the section of this bed is as follows:

	Feet	Inches
Coal	1	3
Clay	7	
Coal	3	

Three workable coal beds are exposed in the valley of Ash creek, in the eastern part of T. 142, R. 101. The lowest is bed R and is at the contact of the light and dark colored divisions of the Fort Union. The following section of this bed appears in the north half of section 14, T. 142, R. 101:

		Feet	Inches
Shale			
Bed R	Coal	6	8
	Clay, gray		14
	Coal	1	4
Shale, exposed above creek		3	

A short distance below this outcrop, and in the same section, all three of the coal beds occur in the steep bluff bordering the valley of Ash creek, the section here being as follows:

	Feet	Inches
Coal	5	
Sandstone	40	
Bed S: Coal	4–5	
Shale and sandstone	35	
Bed R: Coal	6	
Shale and sandstone, to creek bed	20	

The upper coal bed does not correspond in position to any bed found elsewhere and is probably of limited extent. The upper two beds also appear in the northeast quarter of section 13, T. 142, R. 101, where S is 6 feet thick and has been mined on a small scale at the outcrop. The upper bed here measures 5 feet.

Bed S is well exposed just above creek level in the northeast quarter of section 20, T. 142, R. 100, the section being as follows:

		Feet	Inches
Clay wash		2–20	
Bed S	Coal		6
	Clay		3
	Coal	6	
Clay, blue, exposed to creek bed		3	

Considerable coal has been mined here from the outcrop by the farmers of the vicinity, although the locality is not very accessible, being in the bottom of the valley of Ash creek and about 275 feet below the level of the upland.

Very few coal outcrops occur on Green river, in northeastern Billings county. In the southern part of T. 142, R. 99, there is considerable clinker formed by the burning of a coal bed which is perhaps the same as that mined on a small scale near the base of Saddle Butte. No measurement could be secured of this bed since it is everywhere concealed. A workable coal bed is exposed on Green river in the northeast quarter of section 16, T. 141, R. 98, where it has a thickness of 4 feet 4 inches, and a few loads of coal have been taken from the outcrop here.

Two coal beds appear along the upper course of the Knife river in the northeastern corner of Billings county. Their presence is indicated chiefly by clinker along their outcrop in the sides of the valley, but they are exposed in Hungry Mans Butte, in the southeast quarter of section 35, T. 144, R. 98. The lower bed is 3 feet thick and lies 120 feet above the river; the upper bed is 40 feet above and has a thickness of 2½ feet. Both beds are in the upper, dark colored division of the Fort Union.

Coal in the Vicinity of Rainy Buttes.—In East Rainy Butte a bed with a thickness of at least 6 feet occurs 100 feet above the base.[1] This does not represent the entire thickness of the coal, which is partially concealed, and the measurement given above is only for the portion exposed. It is very probable that the same coal bed is also present in West Rainy Butte. It is doubtless to be correlated with one of the lower members of the Sentinel Butte group.

Six or seven miles north of the Rainy Buttes, on the Cannon Ball river, and at a considerably lower elevation, two workable beds of coal occur. They are exposed not far from the east line of Billings county, where the following section appears:

[1] Second Bien. Rep. N. D. Geol. Survey, p. 160.

	Feet
Alluvium	4
Sandstone	5
Clay	2
Coal	4
Clay	4
Coal	5
Clay, to water level	5

COAL IN BOWMAN COUNTY.

No workable beds of coal occur along the valley of the Little Missouri river in eastern Bowman county. The strata of the latter area are the somber beds lying below the light gray and buff division of the Fort Union and the lower portion of this dark-colored series is barren of coal except in thin seams.

The most westerly coal outcrop in the county so far as known is that on Coyote creek, between three and four miles above its mouth, in T. 132, R. 105, where a bed 5 feet 6 inches thick appears along the stream.

Three miles farther up the creek, in section 30, T. 132, R. 104, 12 feet of coal are exposed, the lower portion being covered by talus and deposit from the stream, so that the entire thickness could not be determined.

Coal outcrops at various points along the North Fork of the Grand river, in southeastern Bowman county. A bed is well exposed in the cut bank of the river two miles west of Haley, in section 27, T. 129, R. 100, the section here being as follows:

	Feet
Sandstone and sandy clay	25
Coal	6½
Sandstone, soft, exposed above river	4–6

The coal is mined here from the outcrop, which extends along the side of the valley for 300 to 400 yards, and is used by the settlers living in the vicinity. A bed reported to have a thickness of five to six feet is also mined four miles above, in section 19, T. 129, R. 100. Coal occurs on Spring creek, one of the chief tributaries of the North Fork of the Grand, and is exposed in section 3, T. 129, R. 101. A bed outcrops on Lightning creek, between four and five miles north of Haley and has been mined in section 5, T. 129, R. 99, by stripping off the cover. Coal is also found on Buffalo creek, and between the latter and Lightning creek.

The Consolidated Coal Company has a mine at Scranton, on the Chicago, Milwaukee & St. Paul railroad. The thickness of the coal bed is 22 feet and it contains no clay seams. Its depth below the surface varies from 30 to 140 feet. The mine is located a quarter of a mile from the railroad, with which it is connected by a spur.

A coal bed occurs on the South Fork of the Cannon Ball river, in the extreme southwest corner of Hettinger county, only one mile east of the Billings county line. Here, in section 31, T. 133, R. 97, 3½ feet of coal are exposed, but the bed is partly concealed and its full thickness could not be determined. It is covered by three to four feet of clay and is readily mined by stripping off the cover.

DEVELOPMENT OF THE COAL RESOURCES.

Except at a few points all mining so far carried on in the region under discussion has been by the ranchers and settlers for their own use. The coal is commonly obtained where the beds outcrop along some stream or in a bluff or butte, so that it can be mined with the least expenditure of time and labor. The beds are frequently undermined by river or creek and large masses have fallen off and line the banks, ready to be broken up and loaded into wagons. In many places these outcrops can be reached only in winter when the streams are frozen over, and much of the coal is hauled at this time of the year or during the fall.

Another common method employed is that of stripping off the overlying clay, and where the cover is not over ten or fifteen feet thick this is an easy and inexpensive way of mining. In many cases the cover grows thicker as the bed is followed back into the bluff, so that a limit is reached beyond which stripping cannot be employed.

Probably the first mine to be developed in the region was the one at Little Missouri, across the river from Medora, which belonged to the Northern Pacific railroad. Coal was mined here by the railroad as early as 1884, by means of drifts running in along the bed. Some of the old dump piles and timbers may still be seen.

Several openings have been made in the nine-foot bed at Medora, and considerable coal has been shipped from this mine to nearby towns. The newest entry runs back over 75 feet from the face of the bluff and the cars are pushed out by hand. The thick coal bed at Sentinel Butte is mined at four or five points where it is exposed near the base of the slope, the coal being taken from the outcrop.

The largest mine in the area under discussion is the one recently opened by the Consolidated Coal Company at Scranton, Bowman county, on the Chicago, Milwaukee & St. Paul railroad, to which reference has already been made on a previous page. The coal is blasted from the solid and the mine is equipped with mule haulage.

The material over the coal beds is commonly clay, which makes an insecure roof requiring careful timbering to prevent it from falling. It is therefore customary, when the bed is of sufficient thickness to allow, to leave from six inches to one or two feet of lignite to form the roof of the mine. This makes an excellent roof and one which frequently requires but little timbering except along the main entry.

Future Development.—This part of North Dakota is rapidly settling up and with the large increase of population new mines will be opened in different parts of the field. At the present time nearly every farmer and rancher mines his own coal from the nearest and most accessible bed. In the future an increasing number will obtain their coal from some mine in their vicinity.

The future development of the coal resources of the region will depend to some extent upon how widely the gas engine comes into use, and also upon the cheap briquetting of the lignite. The value of the latter as a source of producer-gas for gas engines has been demonstrated by the tests made at the Fuel-Testing Plant of the United States Geological Survey at St. Louis, where it was found that North Dakota lignite furnishes a rich gas for this purpose. If the gas engine should come into general use, as many believe it will, it would result in a greatly increased demand for this kind of coal. The successful briquetting of the lignite which would allow of its being shipped and stored for a long period without breaking down into small pieces would likewise insure its increased use as a fuel. It seems probable that a commercially successful briquetting process will be found in the near future, and when discovered it will be of great benefit to North Dakota.

THE GEOLOGY OF NORTHEASTERN NORTH DAKOTA

WITH SPECIAL REFERENCE TO CEMENT MATERIALS

BY

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INTRODUCTION.

The area under consideration includes Pembina, Cavalier, and adjoining parts of Walsh and Ramsey counties, comprising townships 157 to 164 N. and ranges 50 to 64 W., or an area of about 2,400 square miles. As may be seen from the accompanying map, the region is well provided with railroads with the exception of that portion lying to the north and northeast of Langdon, in Cavalier county. It is probable that a line will be put through this area in the near future, paralleling the Hannah branch of the Great Northern railroad and midway between it and the Walhalla branch of the same road. The completion of the Northern Dakota railroad to Concrete will also serve as a stimulus and perhaps as a connecting link.

The geology of northeastern North Dakota is of much interest because of the exceptional opportunity afforded for the study of the Cretaceous formations of the region, particularly in the many outcrops of the Pembina Mountains. The area is also of economic importance from the occurrence in it of materials suitable for the manufacture of cement. These and other considerations led the Survey to undertake as detailed a study of the region at time and funds would allow.

This area and adjoining parts of the Red River Valley in Minnesota have received in the past considerable attention from geol-

ogists. The evidences of the former existence of a great lake in the Red River Valley were observed in 1823 by Keating, the geologist of the first scientific expedition to this district;[1] in 1848 by Owen;[2] in 1857 by Palliser;[3] in 1858 by Hind;[4] and in 1873 by Dr. G. M. Dawson.[5] Each of these geologists explored considerable tracts of the lacustrine area, recognizing its limits in a few places, and Hind especially described and mapped portions of the lower beach ridges. Dr. Dawson's work was in connection with the British North American Boundary Commission, and includes detailed notes of the part of this area lying between the Lake of the Woods and the Pembina Mountains.

The excavation of the valley occupied by Lake Traverse, Big Stone lake and the Minnesota river was first explained in 1868 by Gen. G. K. Warren, who attributed it to the overflow from this ancient lake. He made a careful survey of this valley, and his maps and descriptions, with the accompanying discussion of geologic questions, are most valuable contributions to science.[6] After his death, in commemoration of this work, the glacial river that was the outlet of Lake Agassiz was named River Warren.[7]

That this lake existed because of the barrier of the receding ice-sheet was first pointed out in 1872 by Prof. N. H. Winchell.[8]

Considerable work on that part of the area of Lake Agassiz which lies in Minnesota was done by Warren Upham and reported

[1]Narrative of an expedition to the source of St. Peter's river, Lake Winnepeek, Lake of the Woods, etc., performed in the year 1823, under the command of Stephen H. Long, M. S. and Topographical Engineer, London, 1825, Vol. II, p. 3.

[2]Report of a Geological Survey of Wisconsin, Iowa and Minnesota. Philadelphia, 1852, p. 178.

[3]Journals, detailed reports, etc., presented to Parliament, 19th May, 1863, p. 41.

[4]Report of the Assiniboine and Saskatchewan Exploring Expedition. Toronto, 1859, pp. 39, 40, 167, 168.

[5]Report on the Geology and Resources of the Region in the Vicinity of the Forty-ninth Parallel, from the Lake of the Woods to the Rocky Mountains. Montreal. 1875, p. 248.

[6]"On certain physical features of the upper Mississippi river," American Naturalist, Vol. II, pp. 497-502, November, 1869. Annual Report of the Chief of Engineers, United States Army, for 1868, pp. 304-314. "An essay concerning important physical features exhibited in the valley of the Minnesota river, and upon their significance," with maps; Report of Chief of Engineers, 1875. "Valley of the Minnesota river and of the Mississippi river to the junction of the Ohio; its origin considered; depth of bed rock," with maps; Report of Chief of Engineers, 1878, and Am. Jour. Sci. (3), Vol. XXVII, pp. 417-431, December, 1878, (General Warren died August 8, 1882).

[7]Proc. A. A. A. S. Vol. XXXII, for 1883, pp. 213-231; also in Amer. Jour. Sci. (3), Vol. XXVII, Jan. and Feb., 1884; and Geology of Minnesota, Vol. I, p. 622.

[8]Geol. and Nat. Hist. Survey of Minnesota, First Annual Report, for 1872, p. 63; and Sixth Annual Report, for 1877, p. 31; Prof. Winchell also explained in like manner the formerly higher levels of the Laurentian lakes, Popular Science Monthly, June and July, 1873; and the same view is stated by Prof. J. S. Newberry in the Report of the Geological Survey of Ohio, Vol. 1874, pp. 6, 8 and 51.

in the publications of the Minnesota Geological Survey.[1] More detailed work both in Minnesota and North Dakota was undertaken later by the same geologist and the report on it was published by the United States Geological Survey.[2] By the cooperation of the geological surveys of the United States and Canada, Warren Upham was enabled to complete his investigations on Glacial Lake Agassiz, which were published by the United States Geological Survey and in part by the Geological and Natural History Survey of Canada.[3] The report is a valuable contribution to science.

Altitudes in the lake area have also been included in another publication by the United States Geological Survey.[4]

Important observations of the beaches of Lake Agassiz farther northward along the Manitoba escarpment and near the mouth of the Saskatchewan have been made during work for the Geological Survey of Canada by Mr. J. B. Tyrrell.[5]

The Geological and Natural History Survey of Minnesota in Vol. 4 of its Final Report, 1899, considers the areal geology of Kitson, Roseau and Marshall counties, lying in the Red River Valley, and these have many characteristics in common with Pembina and Walsh counties in North Dakota. Dr. C. P. Berkey, did some work in the vicinity of Walhalla and published the results in the Am. Geologist, Vol. XXXV, No. 3, March, 1905. Work of a general character has been carried on in the past in this area by Prof. Babcock and Dr. Leonard of the North Dakota Geological Survey, and is reported in the First and Third Biennial Reports.

Acknowledgments are due Mr. J. M. Melsted, of Gardar, and Dr. R. C. Cliff, of Park River, for their kind assistance in providing horses for carrying on the work. Thanks are due especially to Mr. H. A. Mayo, of Walhalla, for field assistance; and many other citizens of the counties aided in the work.

[1]Geol. and Nat. Hist. Survey of Minnesota, Eighth Annual Report, for 1879, pp. 84-87; Eleventh Annual Report, for 1882, pp. 137-153, with map; and Final Report, Vols. I and II.

[2]U. S. Geol. Survey Bulletin No. 39. The Upper Beaches and Deltas of the Glacial Lake Agassiz, pp. 84, with map.

[3]Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, Vol IV, for 1889-89, Part E, Report of Exploration of the Glacial Lake Agassiz in Manitoba, pp. 156, with two maps and a plate of sections. U. S. Geol. Survey, Mono. XXV, pp. 658. 38 pl. 1896.

[4]U. S. Geol. Survey, Bulletin No. 72, Altitudes between Lake Superior and the Rocky Mountains, 1891, pp. 229.

[5]Geol. and Nat. Hist. Survey of Canada, Annual Report, new series, Vol. III, for 1887-88, Part E, Notes to accompany a preliminary map of the Riding and Duck Mountains in northwestern Manitoba, 16 pages with map. Other papers by Mr. Tyrrell, including descriptions of portions of the Lake Agassiz beaches, are, "Post Tertiary Deposits of Manitoba and the adjoining territories of Northwestern Canada," Bulletin, G. S. A., Vol. I, 1890, pp. 395-410, and "Pleistocene of the Winnipeg Basin, " Am. Geologist, Vol. VIII, pp. 19-28, July, 1891.

PHYSIOGRAPHY.

TOPOGRAPHY.

To the most casual observer it is apparent at once that the area may be divided into three topographic divisions, namely: the Red River Valley; the Pembina Mountains; and the high rolling prairie forming the greater part of Cavalier county. These topographic divisions are well marked and important geologically. There are no outcrops of the sedimentary series in either the first or last divisions while the Upper Cretaceous formations are well exposed in the Pembina Mountains. In the Red River Valley and in Cavalier county geological field work must be confined for the greater part to the consideration of well records, and the study of the physiographic features and the glacial geology.

The Red River Valley in North Dakota lies in general between the Red River or eastern boundary of North Dakota, and range 56 W. The slope of the valley to the north in this area along the eastern boundary of the state is about 1½ feet per mile. Going to the west along the southern boundary of Pembina county the valley bottom rises about ten feet per mile, although the ascent through the first half is only about 3 feet per mile. In the next 8 miles the surface rapidly ascends nearly 400 feet more, as one climbs the Pembina Mountain escarpment, which forms the western boundary of the valley. Along the international boundary the surface rises about 40 feet in 15 miles from Pembina to Neche, and 187 feet in the next 21 miles to the base of the Pembina Mountains. Here as before, the Cretaceous escarpment, known as the Pembina Mountains, rises abruptly, giving an elevation of 1,400 feet above the sea, and rising about 400 feet in two miles. See Plate XX, Fig. 1.

From the foregoing it will be seen that the Red River Valley is a large nearly level plain, which slopes slightly downward to the north and upward to the west. In traversing it from east to west, however, it is at once apparent that there are are upon the surface certain ridges, which extend in a general north and south direction. These usually have only a slight difference in elevation from the valley, commonly 10 to 20 feet on the side towards the Red river, and 3 to 10 feet toward the west; and vary in width from 10 to 25 rods. There are also step-like terraces which extend longitudinally in a north and south direction and slope upward to the west

Fig. 1. Escarpment of the Pembina Mountains in the distance with the level plain of the Red River Valley in the foreground.

Fig. 2. Notch in the Pembina delta cut by Pembina river southeast of Walhalla. The left of the illustration shows the gentle slope to the abrupt eastern edge of the delta.

to a height of 10 to 25 feet. Besides these variations from the general level, there is also one of considerable topographic and economic interest which borders the Pembina Escarpment and is cut by the Pembina river. This is known as the Pembina delta. See Plate XX, Fig. 2.

Previous geological work in the Red River Valley has shown that this valley existed previous to the Glacial Period. During the retreat of the ice-sheet a large body of water was held in this valley by virtue of the presence of the ice-sheet to the north. This is known as Glacial Lake Agassiz. During the early part of the existence of this lake, its outlet was to the south, through the valley now occupied by Lake Traverse and Big Stone and the Minnesota river. As the ice-sheet receded to the north the level of the water of the lake was lowered, and finally found an outlet to the northeast. The complete retreat and disappearance of the ice-sheet gave present day conditions.

During the existence of Lake Agassiz beaches, terraces, and other evidences of shore lines were formed on its margin, and remained after the recession of the ice-sheet and the lowering of the water level. These are evident today and are important in the topography of the valley, as well as economically important as supplies of sand and gravel.

In the southern part of the area of this glacial lake, within 75 miles of its outlet at Lake Traverse, five principal beaches have been observed, and in their descending order have been named, from towns in Minnesota near which they are well exhibited, the Herman, Norcross, Tintah, Campbell and McCauleyville beaches. These shore-lines, however, when traced farther north, are found to become double or multiple, due to an elevation of the northern part as the ice-sheet retreated and its great weight was removed from the earth's crust. In the vicinity of Maple Lake, Minnesota, the Herman beach is divided into five beaches, corresponding to the single Herman beach at the southern outlet. In like manner the Norcross and Tintah beaches are each represented at the north by two, and the Campbell and McCauleyville beaches each by three distinct shore-lines, separated by slight vertical intervals. The northern part of the lake has thus no less than seventeen shore-lines, which were successively formed from the highest to the lowest during the time of the southward outflow through Lakes Traverse and Big Stone and the Minnesota river to the Mississippi.

After the lake obtained its earliest outlet to the northeast, sinking below Lake Traverse, it formed fourteen shore-lines. The first three of these pass near Blanchard, N. D., and these are denominated the Blanchard beaches. The next in descending order is the Hillsboro beach, the succeeding two are the Emerado beaches, and the next lower the Ojata beaches, named similarly from other towns in this state. The remaining six lower beaches are named from localities in Manitoba. In the same descending order they comprise the Gladstone, Burnside, Ossowa, Stonewall and Niverville beaches, the last being double. There are thus in total thirty-one separate shore-lines of this lake in the northern portion of its area; and all of them, excepting the lowest, extend south of the international boundary.

Owing to the conditions under which the field work was carried on and owing to the fact that Mr. Warren Upham did a large amount of detailed work on the shore lines of Lake Agassiz the results of which are contained in Monograph XXV of the United States Geological Survey the writers thought it unnecessary to spend much time on this portion of the work. Instead, some of the more important features and their relations to the remainder of the area were studied, and the writers have drawn freely from the above monograph in the preparation of this report.

Golden Valley. Golden Valley on the north line of sections 4 and 5, Vernon township, has an elevation of 1,185 to 1,195 feet, showing an ascent of 10 feet from east to west in its width of 2 miles. About the same transverse slope, raising the west side of the valley 10 to 15 feet above its east side, is found along its whole extent of 18 miles from the North Branch of the Forest river to the Middle and North Branches of the Park river. From the south boundary of Golden Valley northward, the width of this valley varies from two to only one mile. It is flat, and its bottom and sides consist mainly of clay free from gravel; but wells find gravel intermixed with the clay,probably till, at a depth of a few feet, and about twenty feet from the surface they sometimes encounter a waterbearing stratum of gravel, chiefly made of Cretaceous shale. The highest part of Golden Valley south of the South Branch of Park river, along the north line of sections 27, 28, 29, in Golden township, is 1,199 feet on the east to 1,211 feet on the west. Golden Valley, on the north line of section 29, Lampton

township, is 1,198 to 1,208 feet. In this northern part of the valley limited tracts of its flat area are strewn with abundant boulders up to two feet, and less frequently three or four feet, in diameter. They are probably where swells of till rose nearly to the surface of the water in this strait of Lake Agassiz, so that its fine portions were swept away by waves and currents, to be deposited elsewhere in the valley as clayey silt, leaving the masses of rock which would not be thus removed. Approaching the Middle Branch of Park river, the surface of the Golden Valley continues very smooth and flat, but it ceases to have a continuous ascent from east to west, some portions along the center being depressed a few feet, and thus allowing the formation of shallow sloughs.

The west border of the Golden Valley was the most western shore of Lake Agassiz in its highest stage, but it is only very scantily marked by deposits of beach gravel and sand, because of its sheltered position on the western and leeward side of this narrow strait. From the southeast corner of section 32, Golden township, this shore-line extends in a quite direct course a few degrees west of north through sections 32, 29, 20, 17, 8, and 5 of this township and the east edge of sections 31 and 30, Lampton township. For the next three miles, in the east edge of sections 19, 18, and 7, Lampton township, it runs nearly due north. Thence it turns to a nortwesterly course through section 6 of this township, and section 31, Gardar township. In this vicinity the Golden Valley terminates.

Bushes and trees clothe the slope on the west side of the Golden Valley along its northern part, extending to the south line of Lampton township; but this ascent farther south, also the entire extent of the Golden Valley, the drift hills forming its east border, and the vast plain of the Red River Valley, are prairie, excepting that narrow belts of timber border the water courses.

Smoothly undulating till rises slowly from the west side of the southern part of the Golden Valley, but in section 30, Lampton township, rounded hills of till attain a height of about 100 feet above the valley or 1,300 feet above the sea. Thence northward a smooth slope ascends 50 to 60 feet, or in some portions only 30 or 40 feet, within the first quarter or half mile to the west, succeeded beyond by a moderately rolling surface with less ascent.

A terrace of beach sand and gravel, containing pebbles and cobbles up to six inches in diameter, extends a third of a mile from southeast to northwest, with a width of 5 to 30 rods, in the northwest quarter of section 33, Lampton township, abutting on the west flank of the rolling and hilly deposits of till which make the east border of the Golden Valley. It was formed by currents entering this strait of Lake Agassiz; it has an elevation of 1,213 to 1,195 feet, declining from north to south, and also sinking one or two feet from west to east in its width of 100 to 500 feet, being thus slightly higher along its verge than where it rests upon the adjoining hilly till.

From the north side of section 32, Eden township, Walsh county, an island of rolling and hilly morainic till above the highest level of Lake Agassiz extends, with the exception of two short gaps, twenty miles northward, varying in width from a half mile to a little more than one mile in its southern quarter and from one and one-half to two and one-half miles through the remainder of its extent. This hilly tract, commonly denominated "the mountains," forms the east border of the Golden Valley. In the north part of section 36, Vernon township, it has a depression to about 1,180 feet, which probably was a strait of the glacial lake in its highest stage, an eighth of a mile wide, and a few feet deep. Again in the center of Golden township, it is intersected by the South Branch of Park river, which has a valley a quarter to a half of a mile wide and about seventy-five feet deep. The stream in its course of one and a half miles through this belt descends about fifty feet, from 1,165 to 1,115 feet, approximately. It seems almost certain that a depression slightly lower than the Golden Valley on the west originally extended across this rolling and hilly area where it is cut by this stream; but the erosion of its valley has undermined and removed portions of adjoining hills and ridges, so that its inclosing bluffs now rise 50 to 100 feet, their highest points being about 1,225 feet above the sea, or twenty-five to thirty feet above the east edge of the Golden Valley. All these bluffs and two plateaus left in the midst of the valley are till, yellowish near the top and dark-bluish below.

The elevation of "the mountains" in their southern and narrower portion varies from 1,190 to 1,250 feet above sea level; in the south part of Golden township, 1,200 to 1,260 feet and through the north

half of this township and the south half of Lampton township, 1,200 to 1,275 feet, being highest in section 28 of the township last named, near the northern end of this hilly tract. These prominent accumulations of till, rising in the west edge of the lacustrine area, are probably referable to the ninth or Leaf Hills moraine and appear to have been formed on the western margin of the Minnesota lobe of the ice-sheet, as explained in the general consideration of the area.

The Great Northern Railway at Park River depot is 998 feet above the sea; the natural surface at the southeast corner of section 23, Golden township, on the road leading west from Park River, 1,178 feet. The crest of the upper Herman beach, crossed by this road ten rods west from the point named, it at 1,187 feet, but twenty rods southeast and northwest from the road its height is 1,192 feet. This is a typical beach ridge of sand and gravel, with pebbles up to two or three inches in diameter, mostly limestone and granite. The Cretaceous shale before mentioned is very rare in the till of "the mountains" and in the beaches formed along their east side, indicating that the east limit of this shale is the Pembina Mountains and the western ascent of the Golden Valley, and that the glacial currents by which the drift here was deposited came only from the north and northeast, with no intermixture of currents from west of north.

Lake Agassiz Beaches. The highest beach on the verge of south bluff of the South Branch of Park river, in the southeast quarter of section 23, Golden township, is 1,188 to 1,192 feet high with a basin-shaped hollow on its west side twenty feet lower, which changes southward to a depression of about five feet. The river bluff here shows the depth of beach sand and gravel to be two to ten feet, lying on till. The lower beach, a quarter of a mile farther east, extends from northwest to southeast, in the southwest quarter of section 24, and is 1,167 to 1,170 feet high.

The lower Herman beach is a massive ridge of gravel and sand. extending in a curved course convex toward the east from the northeast quarter of section 2, Golden township, through the southeast part of section 35, Lampton township, with a crest 1,160 to 1,165 feet high; through the northeast edge of section 36, and the southwest corner of section 25, it is 40 to 50 rods wide, with slightly undulating surface, and is 1,160 to 1,167 feet high; near the middle

of the east side of the southeast quarter of section 26, it is 1,165 to 1,166 feet high; and at the quarter-section stake on the north side of this section 26, it is 1,163 feet.

Near the west line of section 23, Lampton township, two Herman beaches abutt upon the east flank of the north end of "the mountains" and extend thence north-northwest two miles to the Middle Branch of Park river. The eastern one, a well-defined ridge of sand and fine gravel passes close west of the quarter-section stake between sections 15 and 10. The elevation of its crest is 1,161 to 1,166 feet, increasing in height from south to north; the descent on the east is fifteen to twenty feet in as many rods, and the depression on the west is three to eight feet deep and ten rods wide. The other beach ridge is forty or fifty rods farther west, parallel with the preceding and similar in form and material, its crest rising slightly northward, is 1,173 to 1,176 feet above sea level. Another distinct beach ridge, but of smaller size, runs in a parallel course through the east part of the southwest quarter of section 9, with its crest at 1,185 to 1,187 feet. These appear to represent together the second and third Herman beaches. The lowest Herman beach in this vicinity passes as a well-marked ridge of gravel and sand through the west part of sections 11 and 2, Lampton township, and the east part of sections 34, 27 and 22, Gardar township, having a height of 1,145 to 1,150 feet, from which there is a descent of five to ten feet on the west.

The upper Herman beach, northward from the north end of "the mountains," forms in the northwest quarter of section 21, and the west part of section 16, Lampton township, a massive broad ridge, composed of sand and gravel, with pebbles up to four or even six inches in diameter, with a crest 1,197 to 1,207 feet high, rising higher northward, where the beach deposit overlies the eastern slope of a wave-like swell of till that rises to 1,212 feet. A small beach ridge belonging to this stage is on the east edge of the southeast quarter of section 8, Lampton township, and is 1,202 to 1,207 feet above sea level. The surface in the western part of the southwest quarter of section 9, is 1,197 feet high, consisting of sand and gravel of this beach to a depth of ten feet. The summit of a smoothly rounded hillock, probably till, but having few or no boulders, in the east edge of the northeast quarter of section eight, is about 1,230 feet; train of beach gravel and sand

extending thence thirty rods southward, rises 1,217 feet above sea level with descent of fifteen or twenty feet on each side. Continuing beyond the Middle Branch of Park river, this highest beach is well developed in a broad ridge running due north through the west part of section 4, Lampton township, with its crest at 1,202 to 1,208 feet. On the east the surface falls thirty or forty feet, and more slowly beyond, while toward the west a descent of ten feet is succeeded by a flat surface of till, which rises slowly from the foot of the beach ridge to a swell at the height of 1,215 to 1,225 feet, a half mile away, forming the east boundary of the Golden Valley. This beach is of sand and gravel, with pebbles up to six inches in diameter. About half of them are limestone; nearly all of the remainder are Archean granite, gneiss and schists; scarcely one in two hundred is Cretaceous shale. Through the west edge of section 33, Gardar township, the elevation of this excellent beach is 1,202 to 1,205 feet, and in the southwest edge of section 28 and the middle of the east edge of section 29, 1,202 to 1,197 feet, decreasing in size and height northward. For a half mile through the southwest quarter of section 33, there is a slight secondary beach ridge, four to nine feet lower which lies about thirty rods east of the foregoing; its crest is at 1,198 to 1,195 feet above sea level sinking a few feet from south to north; it is divided from the higher beach by a continuous depression about three feet deep.

A very massive beach ridge, composed of sand and gravel, with pebbles and rock fragments, the largest only slightly waterworn, up to six inches in diameter, passes a few degrees west of north through the center of section 20, Gardar township, its crest in the south half of the section being at 1,208 to 1,215 feet, and in the north half 1,215 to 1,223 feet. On the east is a descent of twenty to thirty feet within twenty-five to forty rods, and on the west ten or twelve feet from the highest part of the beach within ten rods to a nearly level area of till, 1,211 feet, which sinks forty rods farther west to a long slough, about 1,205 feet high, parallel with the beach and a sixth of a mile wide. Beyond this an undulating surface of till, partly covered with bushes and small trees, rises to 1,250 or 1,275 feet within two miles, and then in massive swells to 1,450 or 1,500 feet within the next two to four miles. These are part of a plateau rising thence more slowly westward, whose boundary for the seventy-five miles to the north-northwest is the conspicuous escarpment called Pembina Mountain.

The north end of this massive beach bears on its crest an artificial embankment 100 feet long from east to west and twenty feet wide, raised two feet above the natural surface, its top being 1,225 feet above the sea. This is ten rods south from where the beach is cut to 1,210 feet by a wide gap as of some ancient watercourse. In the south edge of the southwest quarter of section 17, Gardar township, on the south bank of the North Branch of Park river about ten rods east from the ford of the "Half-breed Road," this beach has an elevation of 1,220 feet.

The North Branch of Park river at this ford is ten to fifteen feet wide and a few inches deep with elevation of 1,203 feet. Its surface at the village of Gardar a mile east, 1,175 to 1,170 feet. Lower Herman beach, passing from south to north along the west side of sections 20 and 17, Gardar township, a third of a mile west of the village, about 1,185 feet.

Sections 17, 8, and 5, Gardar township, rise from 1,190 to 1,200 feet on their east side to 1,220 and 1,225 feet on the west, including, therefore, the upper Herman shore of Lake Agassiz; but they present no considerable deposits of beach gravel and sand. A swell of till, sprinkled with very abundant boulders, nearly all Archean granite and gneiss, up to five feet in diameter, extends from south to north across the line between sections eight and five, having its crest at 1,215 feet, from which there is a steep descent of ten or twelve feet to the west.

The south branch of Cart creek, in sections 31 and 32, Thingvalla township, is bordered by a belt of timber, but it is only a small channel a few feet below the general surface, and is dry through the greater part of the year. Its alluvial gravel, like that of the middle and north branches of Park river, is mostly Cretaceous shale, derived from the gorges eroded in this rock at the sources of these streams in the Pembina Mountain.

Along the western border of Lake Agassiz here and northward into Manitoba extends a prominent wooded bluff, the escarpment of a treeless plateau which from its crest stretches with slow ascent westward. This escarpment commonly called the Pembina Mountain, is a very marked feature in the topography for about seventy-five miles. It is caused by the outcrop, mostly overspread by glacial drift, of a continuous belt of nearly horizontal Cretaceous shale several hundred feet thick. Its [illegible]e coincides nearly with

the west line of Gardar and Thingvalla townships. Thence it continues in an almost straight course, a few degrees west of north, to the international boundary, beyond which it runs north-northwest nearly fifty miles to the vicinity of Treherne. The base of the ascent is about 1,225 feet above sea level, and its crest approximately 1,500 feet, northward to the Pembina river, beyond which the base sinks to 1,150 and 1,100 feet and the crest to 1,400 and 1,300 feet. The width occupied by the slope varies from a quarter to a half of a mile.

The natural surface at the quarter-section stake on the north side of section 32, Thingvalla township, is 1,178 feet above the sea. Sections 32, 29 and 20 of this township are mostly till, smoothed by this glacial lake, the depressions having been filled by leveling down the higher portions, where many boulders partially embedded testify to considerable erosion. A broad beach of sand and fine gravel three to five feet high extends from south to north through the center of section 29, its crest being at 1,180 to 1,182 feet high. This is the third in the series of four Herman beaches. The higher beaches are probably also recognizable one to one and one-half miles farther west near the base of the Pembina escarpment or "second mountain," which is 1,220 to 1,230 feet above the sea; but it is impracticable to trace their course and determine their exact elevation, because woods reach from the base of this escarpment a half mile east where these beaches belong.

The fourth Herman beach is a broad, low swell of sand and gravel extending north-northwesterly through the east half of section 20, Thingvalla township, with elevation of 1,166 to 1,172 feet; through sections 17 and 8, an eighth to a quarter of a mile wide, and 1,161 to 1,173 feet high, having in some places a depth of at least 10 feet, as shown by wells. On the north line of section 20, and again in the north part of section 17, it is intersected by branches of Cart creek, which occupy valleys about 40 feet deep and an eighth to a quarter of a mile wide. Brush and scattered trees grow in these valleys and on the area between them. Toward the east a descent of 30 to 40 feet is made within the first half mile; westward there is only a slight ascent, to about 1,200 feet in one mile; then a more considerable slope, covered with woods, rises 20 to 40 feet to the base of the "second mountain," on or near the township line.

In the west part of section 8, and again near the northeast corner of section 6, Thingvalla township, this beach is intersected by the head streams of Willow creek, in valleys about 35 feet deep. On the north line of sections 5 and 6 of this township the third and fourth Herman beaches are merged in an undulating tract of gravel and sand a half mile wide, which rises from 1,160 feet on the east to 1,184 feet on the west. A well on the west part of this belt found the beach deposit 6 feet thick, underlain by till, which forms the slightly ascending surface next west.

The base of the second Pembina mountain, in the east half of section 31, T. 161, R. 56, varies from 1,235 feet at the south to 1,220 feet northward, coinciding nearly with the upper Herman shore of Lake Agassiz. A well twenty-four feet deep was sunk near the center of section 30, situated about fifty feet above the Tongue river, a few rods back from the verge of its north bluff, and was in soil two feet; gravel, nearly all Cretaceous shale. eight feet; underlain by gravel, nealy all granite and gneiss, with scarcely an intermixture of shale, containing pebbles and cobbles up to four inches in diameter, fourteen feet, yielding a permanent supply of water. This well is close to the base of the "mountain," at an elevation of about 1,230 feet. Its bed of granite gravel appears to be the upper beach, the overlying shale gravel being a delta deposit brought by the Tongue river.

The surface in the northeast corner of the southwest quarter of section 32, T. 161, R. 56, is 1,192 feet. The well here, 14 feet deep, is wholly stratified gravel and sand, being a beach deposit of the second and third stages in the Herman series. The third beach lies about an eighth of a mile east and is a broad ridge of sand and fine gravel, a few feet above the land on its west side, with crest, 1,187 feet.

The fourth and lowest Herman beach, of similar form with the last, but larger, runs a few degrees west of north, through the west edge of section 33, 1,175 feet, with depression of 1 to 5 feet on its west side, and descent of 25 feet within 30 or 40 rods east.

The Tongue river, at a bridge near the center of the south half of section 28, T. 161, R. 56, about 1,110 feet above sea level; bottom land, 10 feet higher; top of the bluffs, about 1,150 feet. Gavins creek in the south half of section 20, is about 1,140 feet high; valley, 40 feet deep and a sixth of a mile wide.

The lowest Herman beach forms a massive ridge of sand and fine gravel in the northeast quarter of section 29, and the east part of sections 20 and 17, T. 161, R. 56, with its crest at 1,175 to 1,180 feet.

Pembina Delta—The largest tributary of the Red river in North Dakota is the Pembina river, which has cut a valley about 400 feet deep and a mile wide in the plateau of the "second" Pembina Mountain. During the recession of the ice-sheet this stream was much larger than now, being for a time the outlet of glacial lakes in the basins of the Souris and Saskatchewan rivers.[1] The delta deposited in the margin of Lake Agassiz by the Pembina river, swollen by a great affluent from the melting ice fields at the northwest, beyond the present limits of its basin, extends about sixteen miles from south to north, and has an average width of about five miles with a maximum thickness exceeding 200 feet. Its mean thickness is probably not less than 150 feet, giving it for its volume about two and one-third cubic miles, spread upon an area of 80 square miles. Four-fifths of this delta lies south of the Pembina river reaching nearly to the Tongue river.

Its elevation in the northwest part of section 17, T. 161, R. 56, is 1,200 feet; thence northward it rises slowly in two miles to 1,225 feet in the east part of section 6; and in sections 30 and 31, T. 162, R. 56, it varies from 1,220 to 1,227 feet. From this crest of the southern part of the delta it slopes slowly east and northeast to 1,080 and 1,090 feet at its eastern border, in sections 25, 24 and 13, which coincides nearly with the east line of T. 162, R. 56. Deep valleys, with frequent tributary ravines, have been eroded in it by several small streams. Westward the delta reaches to the base of the second Pembina Mountain, the belt, a half to one mile wide, next beyond the crest, only about 5 feet lower, being a very flat, beautiful prairie, which rises slowly, like the crest, from south to north. The elevation of this belt in section 18, T. 161, R. 56, is 1,190 to 1,195 feet, and in the middle of the east edge of section 36, T. 162, R. 57, 1,221 feet. Farther west there is an ascent of about 1,240 feet at the base of the "second mountain." Wells on this area penetrate only beds of sand and gravel easy to dig and needing to be curbed to prevent caving. A large proportion, probably half, of the gravel is formed of Cretaceous shale. Water is obtained at depths varying from 25 to 60 feet.

[1]Mon. XXV, U. S. Geol. Survey, pp. 267-274; Geol. and Nat. Hist. Survey of Minn., Ninth Ann. Report, 1880, p. 342; Hinds Report of the Assiniboine and Saskatchewan Exploring Expedition, 1895, pp. 118-168.

The part of the Pembina delta thus far described is divided from its central and higher part, which is shown in Plate XXIII, by a depression about a mile wide, through which a portion or whole of the river flowed during much of the time that this delta was being formed. In the southwest corner of section 18, T. 162, R. 56, this depression is 1,205 feet abovve the sea, being 20 feet lower than the area on the south. It extends eastward with a slow descent, and rises westward to 1,215 feet, just east of the Little Pembina river, in section 15, T. 162, R. 57. This stream flows through the escarpment of the "second mountain," to its junction with the Pembina river, thus leaving the depression just described, which would seem to be its more natural course and taking in its stead a channel that is eroded through a portion of the delta 50 feet higher.

The most elevated point of this delta is about 1,270 feet above the sea, near the northwest corner of section 11, T. 162, R. 57, east of the Little Pembina and south of the Pembina river, and is nearly 300 feet above the junction of these streams, one and one-half miles distant toward the northwest. Section 12 of this township and the west part of section 7, T. 162, R. 56, slope from 1,225 feet on the south to 1,215 feet on the north; their southern part is the highest land crossed between the depression before mentioned and the Pembina river by the line dividing these townships. The level of Lake Agassiz in its highest stage here was 1,220 or 1,225 feet above the sea, being 50 feet below the top of the Pembina delta, as is shown by the beach line of this level, 1,226 feet, in the central part of section 7, where an eastward descent begins. This is the east verge of the nearly flat area of the delta in sections 12 and 7. Like all of this delta deposit the material here is sand and gravel, covered by a fertile soil. A small proportion of the pebbles of this gravel is limestone; a large part is Cretaceous shale, but more was derived from Archean formations of granite and gneiss.

The second Herman beach, a ridge of the usual form, is crossed by the road near the east side of the northeast quarter of section 7, T. 162, R. 56, descending from 1,212 feet to about 1,200 feet in a distance of a third or a half of a mile from north to south.

A well 110 feet deep, in the northwest quarter of section 8, T. 162, R. 56, at an elevation of 1,189 feet, is in stratified sand and gravel, with pebbles up to six inches in diameter, fully half Cretaceous shale. Water comes in coarse sand at the bottom, filling the low-

est two feet. Another well of the same description, but 137 feet deep, is a mile farther east, in the southwest quarter of section 4, 1,192 feet above the sea.

On the road from Olga to Walhalla the crest of the east margin of this delta is crossed in the north part of section 33, Walhalla township, about two miles southeast from the village of this name. Its elevation is 1,190 to 1,196 feet above the sea.. This is a beach accumulation, belonging to the third Herman stage. Toward the west and southwest the undulating delta plateau is 10 to 30 feet lower for a width of one to one and one-half miles, averaging about 1,175 feet. Northeast from the crest of this road a short descent is made to a prairie terrace, 30 to 60 rods wide, varying in elevation from 1,182 to 1,169 feet, but mainly within 2 feet above or below 1,175 feet. In general the edge of this terrace is its lowest portion. Thence a very steep descent of 169 feet is made on the road from 1,173 to 1,004 feet, this being the conspicuous wooded escarpment called the "first mountain." It is the eroded front of the great Pembina delta, the eastern part of which originally descending more moderately, has been swept away by the waves and shore currents of the lake during its Norcross, Tintah, Campbell and McCauleyville stages. From section 33 the "first mountain" extends southeast to sections 13 and 24, T. 162, R. 56, and northwest across the Pembina, passing just southwest of Walhalla and onward to sections 10 and 3, T. 163, R. 57. Its highest part is intersected by the Pembina river, above which it rises on each side in bluffs of gravel and sand, 200 to 250 feet high, with their crest one-half mile to a mile apart. From this upper portion the delta slopes down gradually toward the southeast and toward the northeast and north, extending only two to four miles north of the Pembina.

The surface at Walhalla is 968 to 994 feet; Pembina river at the bridge, a third of a mile east of Walhalla, at low and high water, is 934 to 943 feet.

The highest part of the Pembina delta north of the Pembina river in sections 25 and 26, T. 163, R. 57, is 1,210 to 1,230 feet, rising slowly from east to west; in the west half of section 26 and the east edge of section 27 it is depressed to 1,225 and 1,220 feet; but beyond this it rises to 1,235 and 1,240 feet, next to the foot of the "second mountain."

The surface at the quarter-section stake on the north side of section 26, T. 163, R. 57, is 1,191 feet. The crest of the third Herman beach five rods south of the stake, is 1,197 feet above sea level, from which there is a descent in five rods to 1,192 feet and in 15 rods to 1,180 feet. This beach curves thence to the northwest and north, and in the opposite direction runs east-southeast two miles to near the center of section 30, Walhalla township, where its elevation is approximately 1,192 feet. Other shore lines of the Herman group were not noticed north of the Pembina river.

From the erosion of this first Pembina Mountain, by the glacial Lake Agassiz during its recession, large quantities of gravel and sand were swept southward, notably during the Campbell stages of the lake, when they were deposited in a very massive curving beach ridge that crosses the Tongue river in the west part of T. 161, R. 55, about seven miles west of Cavalier.

Through Eden township, and the next 5 miles northward to the vicinity of Edinburgh, the Norcross shores on the eastern side of "The Mountains" lie mostly within a half mile to one mile from the highest Herman shore. Upon this somewhat steep slope, intersected by numerous ravines, neither the Herman shores nor the Norcross shores are so distinctly traceable as usual, either by beach deposits or by lines of erosion.

From the northern end of "The Mountains," near Edinburgh, the Norcross shore lines run north-northwestward, passing about two miles east of Gardar, less than a mile west of the village of Mountain, and through the eastern half of section 33, T. 161, R. 56. At the locality last named the upper Norcross shore lies about a third of a mile east of the lowest Herman beach, and is marked by a ridge of gravel and sand 10 to 20 rods wide, with a depression of one to four feet on its west side and a descent of about six feet in a few rods to the east. Its crest has an elevation of 1,143 to 1,145 feet, being thirty feet lower than the adjacent Herman ridge.

The outer border of the plateau of the Pembina delta, forming the "first Pembina Mountain," was the Norcross shore of Lake Agassiz. After the Herman stage of this lake all its lower levels with southward outflow washed the front of the Pembina delta, carrying away much of this deposit southward and eastward, and producing the steep escarpment, mostly 100 to 175 feet high, by which it is bounded on the east.

On the more gradually sloping northern edge of this delta, two to four miles west of Walhalla, a beach formed during the lower Norcross stage passes from east-southeast to west-northwest. In the north half of section 23, T. 163, R. 57, where its crest has an elevation of 1,135 to 1,120 feet, it is a broad, low ridge, chiefly of sand, with fine gravel, containing pebbles up to one or two inches in diameter. Most of the gravel is derived from the Cretaceous shale of the Pembina Mountain, but a part is of limestone and crystalline Archean rocks. A depression of five or six feet, fifteen to twenty rods wide, lies on the southern side of the beach, away from the lake, and its northern side falls off into the lacustrine area with a gentle slope.

Two miles farther northwest the Norcross shore-lines, with the entire Herman series, leaving the Pembina delta, sweep into the great Cretaceous escarpment of the second Pembina Mountain with which they coincide for several miles northward, crossing the international boundary.

From Eden township northward to the Pembina delta the courses of the Tintah shores, though not exactly traced, are known very nearly from the rate of eastward descent of the land and from the mapped course of the next succeeding Campbell beach. At one locality a Tintah beach ridge was noted, near the middle of the line between sections 19 and 18, Kensington township, about two miles northward from the town of Park River; but for the next two miles or more northward there is a rather irregularly rolling surface, with no definite beach observable.

The Tintah shores are only a short distance below those of the Norcross stages on the flanks of the Pembina delta and on the lower part of the Pembina Mountain escarpment for several miles thence northward.

Beyond Conway, for a distance of about thirty-five miles, the Campbell shore-line, passing through the west edge of the town of Park River and close by the east side of the village of Mountain, is almost uninterruptedly an eroded escarpment of till, with eastward descent of twenty to thirty feet, or rarely forty feet, within an eighth of a mile or often a less distance. At Park River the Campbell escarpment falls rather abruptly from 1,035 to 1,015 feet above the sea; and thence a gentle slope of till sinks about fifteen feet lower in a half mile east to the McCauleyville beach and the

railroad. In the northwest corner of Dundee township, ten miles north of Park River, the escarpment falls from 1,045 to 1,015 feet, being steep in the upper half, which consists of till; then it descends more slowly a few feet, also in till, with frequent boulders; and its lower third is a somewhat steep slope of beach sand, and coarse gravel.

From the foot of the escarpment a smoothed surface of till slopes gradually eastward, having an estimated descent of 100 feet within three miles. In section 2, Gardar township, the crest of the escarpment, at 1,045 feet, bears a slight ridge of beach gravel and sand, two to three feet above the surface of till on the west; but the face of the escarpment, here falling twenty-five feet within thirty rods to the east, is till, enclosing plentiful boulders of granite and gneiss. A few miles farther north, at a distance of about one mile south of the village of Mountain the steep slope falls from 1,040 to 1,000 feet, and is covered with a beach deposit of gravel and sand from 1,030 to 1,020 feet, while the higher portion and a broader belt forming its foot, like the lower land extending eastward, are till. At Mountain this shore descends thirty feet, from 1,045 to 1,015 feet, within a distance of about twenty-five rods. It is wholly till, with no associated beach formation, as also are the more gentle slopes on both sides, sinking toward the east and rising westward. During all the Campbell stages of Lake Agassiz erosion was in progress upon this long escarpment; but in some localities the action of the waves in cutting away and removing till was temporarily changed, alternating with accumulation of shore deposits of wave-brought gravel and sand.

Erosion of the base of the "first Pembina Mountain"—that is, the front of the Pembina delta, along a distance of six miles to the southeast from Walhalla—supplied an extraordinary, massive Campbell beach or embankment, verging from a quarter of a mile to nearly one mile in width, which extends eight or nine miles in a curving course, convex to the southeast through sections 5, 8, 17, 20, 29 and 30, T. 161, R. 55, and the south half of section 25, the southwest quarter of section 26, and the west half of section 35, T. 161, R. 56. This broad belt consists of gravel and sand, fifteen to forty feet or more in depth, which were carried southward by the shore currents of Lake Agassiz in its Ca ll stages, the greater portion being transported six to twelve ifteen miles.

The crest or somewhat plateau-like top of the embankment in its course of six miles south of the Tongue river has an elevation of 1,020 to 1,030 feet above the sea. In its narrower part north of the river, its crest ranges from 1,028 to 1,033 feet along the first mile from the river; 1,030 to 1,035 feet along the next mile; and 1,035 to 1,045 feet, averaging 1,040 feet, in its third and most northern mile; passing through the southwest edge of section 29, T. 162, R. 55, where it becomes an ordinary beach ridge only twenty to thirty rods wide, with descent of fifteen feet to the east and five feet to the west. The process of accumulation of the extensive embankment was by transportation of its material along the shore that is marked by the beach ridge, and by building it thence out into the lake in this long hook bent to the west, which grew gradually in length and in height until it rose to the lake level, its growth afterward being by addition to its width. From its eastern verge a slope of the same gravel and sand falls thirty to forty feet in a third or half a mile, to a south to north belt of dunes and sand ridges, ten to fifteen feet high, which appear to represent the McCauleyville beaches. West of this embankment a basin fifteen to forty feet below it, mostly consisting of fertile land, well drained by the Tongue river, extends six miles from south to north, with a maximum width of about three miles, lying between the embankment and the southeastern border of the Pembina delta, which was the lake shore during the Norcross and Tintah stages. The prevailing course of the coastal currents of Lake Agassiz, and of the transportation of its beach material here and elsewhere, on both its western and eastern sides, was from north to south, as now on Lake Michigan, due then and now to the prevailing directions of the winds, and especially gales and severe storms, when the broader and higher portions of the beaches were chiefly amassed.

At Walhalla and northwestward the Campbell shore-lines run along the base of the escarpment of the Pembina delta, where its steep descent is succeeded by a more gentle slope. The principal lower Campbell shore, from one-half mile west of Walhalla to two miles northwest, is in part a well-developed beach ridge, with crest 1,030 to 1,035 feet above the sea, but is mostly a terrace eroded in the delta deposit, falling from 1,040 to 1,020 feet approximately. In the northeast part of section 14, T. 163, R. 57, about three miles northwest of Walhalla, the upper Campbell shores form such a

terrace, which falls from 1,075 to 1,035 feet; while a more moderate slope of sand and fine gravel below, to 1,025 feet at the road running from Walhalla, probably represents the lower Campbell stage.

Three miles farther northwest and about one mile south of the international boundary a terrace of gravel and sand in the west part of section 34, T. 164, R. 57, marks the Campbell beach of the lake. The front of the terrace rises steeply from 1,015 to 1035 feet above the sea, and its top has a further gentle ascent of ten to fifteen feet in its width of about fifty rods to where it abutts on the base of the lowest escarpment of the Pembina Mountain, which rises from 1,050 to 1,100 feet. From the top of this escarpment a terrace or plateau of till and underlying Cretaceous shale extends across a width of three-fourths of a mile west to the principal Pembina escarpment. The upper Campbell level probably passed along the top of the sand and gravel terrace, near the elevation of 1,045 feet; the second level of the series was near the verge of this terrace, approximately 1,035 feet; and the third and lowest stage coincided with the lowest third of its steep front.

Through a distance of about twenty-five miles from Park River to the Pembina delta, the McCauleyville shore, probably marked throughout by a deposit of gravel and sand, lies about a half mile east of the Campbell escarpment.

A belt of low dunes in sections 28, 21, and 16, T. 161, R. 55, running along the eastern base of the great Campbell embankment that was built out to the south from the front of the Pembina delta, probably records the McCauleyville stages, approximately at 1,000 to 980 feet above sea level. North of the Tongue river the McCauleyville shores lie a third to a half of a mile east of the Campbell embankment and beach ridge for a distance of five miles. Thence through the next six miles, extending northwest to the Pembina river and Walhalla, they run along the base of the first Pembina Mountain, which is the very steep ascent, 100 to 175 feet high, of the eroded east border of the Pembina delta plateau.

The road from Olga to Walhalla, coming down from this plateau about a mile southeast of the Pembina river, crosses at its foot a terrace of sand and gravel, thirty to fifty rods wide, having an elevation of 1,000 to 1,009 feet above the sea, which was formed during the upper McCauleyville stage. The highest part of the terrace is at the point where it rests against the "mountain," and its surface

descends a few feet to its northeastern verge. There is next a somewhat rapid slope to 985 feet at the bottom of a depression about fifteen rods wide, beyond which the road passes over the beautifully developed lower McCauleyville beach. This ridge is twenty to thirty rods wide, with smoothly rounded top at 990 to 993 feet, very level along a visible distance of a third of a mile or more of its course from southeast to northwest. Its lakeward northeastern slope falls about twenty feet within twenty-five rods, and from its base a slower descent continues eastward.

All the land of this vicinity, including the plateau and front of the delta, the terrace and beach ridge, the intervening hollow, and the flat country on the east, consists of gravel, sand and fine silt, belonging to the delta as it was originally deposited, or as it has been worked over by the lake waves during later stages. Indeed, proceeding eastward thirty miles to the Red river at Pembina, St. Vincent and Emerson, one crosses only the fine silt which was of like origin with the delta but was carried into the lake, or the similar alluvial beds that have been laid down from floods of the Pembina, Tongue and Red rivers since Lake Agassiz was drained away.

Between Walhalla and the international boundary the McCauleyville shore lines lie on the western margin of the flat expanse that stretches from the Red river to the Pembina Mountain, being a quarter of a mile east of the first conspicuous westward ascent. In section 2, T. 163, R. 57, about two miles south of the boundary, they form a tract of sand and fine gravel, forty to fifty rods wide, drier than the adjoining surface on the west and east, passing by Elm Point, the eastern limit of the groves, at that place consisting mostly of large white elms, which extend outward from the wooded Pembina escarpment along springy watercourses scarcely depressed below the general surface. The elevation of this gravelly tract is 997 to 1,002 feet. It is not a distinct ridge or even swell, and is recognizable chiefly by the contrast of its comparative dryness, which has caused it to be selected as the site of farmhouses. The adjoining moist and springy land on the east descends fifteen or twenty feet in the first third of a mile, but thence the surface sinks very slowly to the axial lowest part of the lake basin in this latitude at the Red river, its gradients in this distance being gradually diminished from fifteen feet to only two or three feet per mile.

In the portion of the Red River Valley under consideration the Blanchard shore lines lie to the east and close to the McCauleyville beach. They continue close together and nearly parallel but this part of the Blanchard shore has not been followed with leveling.

Although three pauses in the crustal uplift are shown near Hillsboro, on the beach deposits of the same name, yet those stages seem to be united elsewhere. This shore line has a general northwest and north-northwest course, excepting that it deviates to a north-northeastward course for fifteen miles, between the North Branch of Park river and Tongue river, turning thus aside to pass by the Pembina delta. Although the course of the Hillsboro beach is mapped approximately, yet its height is known by leveling in only one place, near the centre of section 15, Walhalla township, about two and one-half miles northeast of the town of Walhalla, where the top of the beach is 940 feet above the sea, rising fifteen feet above its base twenty rods distant to the east and bordered by a depression of two to five feet on the west.

In the southern part of Pembina county the Emerado shore curves to a north-northeast course, passing by Crystal to Willow creek, and thence runs nearly north, crossing the Tongue river about a mile west of Cavalier. Along a distance of six miles north from Willow creek a low and broad secondary beach ridge, or more likely in part an offshore sand deposit that was formed a few feet below the lake's surface, has an elevation of 890 to 895 feet, with slopes sinking a few feet below this on each side. The adjoining surface is lacustrine silt, deposited in front of the Pembina delta, and the ridge is fine sand which has been somewhat gullied and hummocked by the wind.

Between the Tongue and Pembina rivers and onward to the international boundary this beach takes a northwestward course. Turning to that direction about two miles northwest of Cavalier, it thence runs nearly straight ten miles to St. Joseph, being through the greater part of the distance a typical beach ridge of sand, with scanty layers of very fine gravel. Its crest is mainly 892 to 898 fee above the sea, having a gradual ascent from south to north; but as it approaches St. Joseph and the Pembina river its last two miles rise 900 and even 905 feet above sea level. Th[illegible] pes fal commonly five to ten feet northeastward and two t[illegible] e feet southwestward. The depth of the beach deposit is [illegible] me as

, eastern slope, with hard and dark stratified clay be-
:tion 2, and again in section 13, T. 162, R. 55, lying
iiles southeast of St. Joseph, this beach widens into
:ach of which has a width of a quarter of a mile or
ightly raised, like the typical narrower ridge, above
ırface of clayey lacustrine and alluvial silt. About
:he Pembina river the Emerado level of Lake Agassiz
scarpment of erosion, which passes north-northwest-
heast corner of section 17, T. 163, R. 55. Within
s from west to east it descends about ten feet, from
bove the sea, approximately.

of the Red River Valley under consideration the
e found as shown approximately mapped. They
isconnected accumulations of sand and gravel,
ve sea is about 880 feet, and rise from two to
surface to the east.

er consideration, as shown on the map, the Glad-
bout four miles west of Grafton, two to three
arn, St. Thomas and Glasston, about four miles
nd Bathgate, and five miles west of Neche. The
by Warren Upham, in Grand Forks county, are
sion in the lacustrine and alluvial silt.

Burnside shore is known approximately and
visionally on the map, Plate XXVIII, in ac-
levations ascertained by railway surveys, but
n observed to be clearly traceable by either a
ge or an eroded escarpment. It lies on the
which adjoins the Red river, a surface most
reservation of definite shore lines.

time of the Ossawa beach extended into the
sixty miles, but the only part of this shore
ized and examined south of the international
in Pembina county. In sections 21, 16 and
south of the Tongue river, at a distance of
rom Hamilton, two or three parallel low,
observed, elevated two to four feet above
and general surface, their height being
et above the sea. They run from south-
eir continuation north of this river was

noted at the same height four to six miles northwestward in sections 36 and 25, Neche, about two and one half miles east-northeast from Bathgate. Both the ridges and the adjoining surface are fine silt.

Lake Agassiz, at the time of the Stonewall beach, probably extended on the flat Red River Valley to a distance of about twenty-five miles south of the international boundary, being some fifteen feet deep at Emerson, St. Vincent and Pembina, while over the site of Winnipeg its depth was about sixty feet. A somewhat ridged contour upon the otherwise very flat surface of fine alluvial silt was noted six to seven miles east of Hamilton and Bathgate. The wave-like and almost beach-like undulations, rising two to four feet above the depressions which separates them and above the general level, runs north-northwesterly through the east part of section 11 and the central part of section 2, T. 162, R. 52, close southeast of the Tongue river. Similar contour was also noticed in the continuation of this course within a few miles northward between the Tongue and Pembina rivers. The height of this belt is about 805 feet above the sea.

The southern end of Lake Agassiz in the Niverville stage was near Morris, Manitoba and its level was fifteen to twenty feet above the surface where the city of Winnipeg is built.

Pembina Mountains. A very remarkable series of highlands, forming the eastern limit of the elevated plain of the northern part of North Dakota and of western Manitoba and the Saskatchewan region, extends in a north-northwest course 400 miles, from the Pembina Mountains to the Pasquia Hills. Along much of this distance, a steep, mountain-like escarpment, which was the west shore of Lake Agassiz, rises 500 to 1,000 feet above the bed of that lake, now the low plain bordering the Red river and the great lakes of Manitoba. Topographically, this line of conspicuous highlands is allied with the Coteau des Prairies by their forming together that western ascent from the broad, continuous valley plain, which in its southeast part passes from the Red River Valley to the lowlands of the basin of the Minnesota river. Both the Coteau des Prairies and the Manitoba escarpment consist, beneath their drift covering, of nearly horizontal Cretaceous shales, whose continuation has been removed by erosion on both sides of the Coteau, but only east of the escarpment.

The southern end of the Pembina Mountain, where it is reduced to rounded hills, about 100 feet above the lowlands at their east base and 1,300 feet above the sea, is in section 30, T. 158, R. 56, between the south and middle branches of Park river. Thence for the next five miles northward this ascent is merely a slope that rises fifty or sixty feet, or in some portions only thirty or forty feet, within a quarter of a mile from east to west, succeeded beyond by a moderately rolling surface with slower ascent westward. Along the west line of townships 159 and 160 of range 56 this highland rises gradually in its course from south to north, attaining an elevation about 1,500 feet above the sea; and it holds this height quite uniformly northward to the Pembina river, in the south part of township 163, R. 57, about five miles south of the international boundary. It is a prominent wooded bluff, some 300 feet high, extending in a very direct course from south to north or a few degrees west of north. From its southern end to the Pembina river the base of this escarpment is 1,200 to 1,225 feet above sea level. The width occupied by its slope varies from a half mile to two or three miles, and from its crest a treeless plateau, having a moderately rolling surface, stretches with slow ascent westward. North of the Pembina river its crest sinks to about 1,400 feet, and its base to about 1,025 feet at the international boundary.

Where the Pembina river cuts through this escarpment, entering the area of Lake Agassiz, the eroded eastern front of its delta deposit forms another conspicuous bluff, about 200 feet high, falling in a steep, wooded slope from 1,175 to 975 feet, approximately, above the sea level. The delta bluff, called the "First Pembina Mountain," is composd of sand and gravel, and lies about five miles east of this more prolonged line of highland, which is known in that vicinity as the "Second Pembina Mountain." The latter, throughout its entire extent both in North Dakota and Manitoba, is caused by the outcrop of a continuous belt of almost level Cretaceous strata, mostly overspread by glacial drift. (See Plate XX.)

The ascent of this highland on the international boundary, where it occupies a width of about one and a half miles, is described by Dr. G. M. Dawson as follows:

"The eastern front of the Pembina escarpment is very distinctly terraced, and the summit of the plateau, even at its eastern edge, thickly covered with drift. The first or lowest terrace, which is

about one-third from the prairie level toward the top of the escarpment, does not seem to preserve exactly the same altitude. On the boundary line its height above the general prairie level was found to be about ninety feet, a second terrace 260 feet, and that of the third level, or summit of the plateau, about 360 feet. The surface of the first terrace, which is here wide, is strewn with boulders, as is also that of the second terrace and plateau above. These are chiefly of Laurentian gneiss and granite, but a few smaller ones of limestone occur. The banks of ravines cutting the top of the plateau and draining westward into the Pembina river show in some places a great thickness of light colored, yellowish, marly drift, with few boulders imbedded in it."

The topographic region of the Pembina Mountains is bounded by the escarpment on the east and on the west by the west line of range 57 as far north as the south line of township 162, and thence north by the west line of range 58 to the boundary. This northwest extension of the region is due to the deep valleys of the Little Pembina and Pembina rivers.

All of the streams in this region have cut deep valleys from 200 to 500 feet deep, which has given rise to the mountainous topography. Most of the stream valleys dwindle down to mere depressions within a few miles west of the escarpment. In the case of the Little Pembina, the valley is deep as far west as the west line of range 58, while the valley of the Pembina river is deep and precipitous far to the northwest in Manitoba. (See Plate XXI.)

In section 6, Fremont township, there is a peculiar hillock known as "Heart Mound" and to the northwest about one and a half miles, there are a series of similar mounds known as the "Black Hills." These rise above the general level of the country from fifty to 100 feet. They are formed of Pierre shale, and are remnants left by erosion. (See Plate XXIII, Fig.2.)

Stretching westward from the Pembina Mountains, lies a comparatively flat plain with slow westward ascent, and gently undulating surface. It includes the whole of Cavalier county and is formed by the westward extension of the flat lying Cretaceous strata of the Pembina Mountains covered by glacial drift of variable thickness. The relief of this region, although greater than that of the Red River Valley, is, however, quite small, and is an ...ple of high rolling prairie. The swells of this prairie have ...xes

Fig. 1. Deep valley of Little North river near its junction with Pembina river. Shows Niobrara outcrops. Deep rugged valleys are characteristic of all streams near their emergence from the escarpment.

Fig. 2. Valley of the Little Pembina river, cut in Pierre shale, north of Stilwell. Shows the manner in which the valleys flatten out and merge into the rolling prairie west of the escarpment.

as a rule running in either a north-south or an east-west direction. The swells are usually about ten feet above the intervening depressions and rarely exceed twenty-five feet.

DRAINAGE.

The Red River Valley is well supplied with streams, but is imperfectly drained, due both to the lack of relief of its surface and also to the character of its soil. The main drainage line of the region is the Red River of the North which forms the eastern boundary of North Dakota. Its clay banks are of moderate height, from twenty to forty feet, and usually rise gradually on one side and with a more precipitous slope on the other. The steep banks are on the outer side of the bends of the river. There is little or no bottom land. The maximum variability in the height of the river is a little less than forty feet.

The drainage of the region is carried to the Red river by two main tributaries, the Park river on the south and the Pembina river on the north. The three branches of the Park river, are known as the South, Middle and North branches. These unite to form the main stream about three miles northwest of Grafton. The South Branch of Park river, rising in southeastern Cavalier county, flows in a southeasterly direction to the west line of range 56, and then flowing in an easterly direction to the main stream drains a belt of country about four miles wide lying to the north of it, and a belt about six miles wide lying to the south. The Middle Branch of Park river rises in southeastern Cavalier county, just east of the South Branch. It flows in a generally easterly direction to the west line of range 54, and thence southeast to its junction with the main stream. It drains a belt of country about three miles wide on either side, except on the northern side of the point of its change of direction to southeast, where it lies close to the North Branch. The North Branch rises in Cavalier county between Milton and Osnabrock and flows in a general southeasterly direction to its junction with the main stream. It drains a strip of country about three miles wide on either side. Cart creek is the main tributary of the North Branch of Park river and joins it in the southeast quarter of section 3, Glenwood township. Cart creek is formed by the junction of many small streams rising just west of the Pembina escarpment and nearly all joining the main stream west of the east boundary of Crystal township. Cart creek

drains a fan-shaped area about fifteen miles wide to the west, and three miles wide along the main stream. All of the smaller streams of the foregoing are dry or nearly so in the summer months.

In the Red River Valley the area lying between the Park and the Tongue and Pembina rivers, and especially east of the Neche line of the Great Northern Railway, is imperfectly drained. There are many depressions in the surface of the valley which are known as sloughs and contain much water in the spring and fall but are dry in the summer. A very accurate leveling of this section has been made by the state in cooperation with the United States Department of Agriculture, and much drainage work and ditching is now in process of construction in this area. Many of these sloughs contain alkaline or salt waters.

The Tongue river is the principal tributary of the Pembina river in the Red River Valley. Rising about eight miles west of the escarpment and with its branches from the Pembina delta, it flows in a general northeast course to Bathgate and then in an irregular east and north direction to its union with the Pembina in Pembina township. It drains an area of about four miles wide to the south and about eight miles wide to the north, and contains water the year round.

The Pembina river after leaving the Pembina delta at Walhalla flows in a general northeast direction to Neche, and thence east by a little south to its junction with the Red river at Pembina. It carries much water the year round, and is the most important stream of the area. It drains a strip of country about five miles wide on either side. Its channel is only twenty to forty feet deep.

In the Red River Valley all of the streams have banks of lacustrine soil and clay, and their depth of channel varies from five to forty feet, with the exception of the Red river, whose channel is much deeper, some eighty feet.

In the Pembina Mountain region the streams have cut deep channels through the drift and underlying Cretaceous strata. At their point of emergence from the escarpment, the valleys of these streams vary from 200 to 450 feet in depth. In the majority of cases, that of the smaller streams, the channels change to mere depressions in the surface from three to six miles west of the escarpment. Notable exceptions to this are the valleys of the South Park, North Park, Tongue, Little Pembina and Pembina rivers. In the

Fig. 1. Wide valley of the Pembina river in the Pembina delta at Walhalla. Part of an abandoned ox-bow lake in the foreground. The delta is composed of silt at this point.

Fig. 2. Wide, deep valley of Pembina river in section 24, T. 163, R. 58. Shows wel
developed --bow bend of the river. In the middle distance, at the right of th
illustr- Little North river enters from the north.

Fig. 1. View looking southwest from bluff in northeast quarter of section 34, T. 163, R. 57. In the middle distance at the right is the Pembina river, which flows in front of the wooded bank in the foreground. In the middle distance is the Little Pembina river, which joins the Pembina in the foreground, to the left, outside the figure. In the middle distance in the center is a remnant of the Pembina delta with a road winding up from the valley. In the distance is the Pembina Mountain escarpment, rising above the delta.

Fig. 2. Heart Mound, in section 6, Fremont township. A remnant of Pierre shale on the high plain to the west of the Pembina Mountain escarpment.

: valleys fade out about ten miles west of the ttle Pembina river does not pass into the Red It rises west of Stilwell and flows in a general r about six miles where it turns to the south-:e from the escarpment it runs east for a short ıa delta, and then flows in a northerly direc-'e line between the escarpment and the delta bina in section 34, Fremont township. En- the Pembina river runs in a deep valley t of the escarpment in a southeasterly direc- escarpment it continues in a northeasterly ·unning through the Pembina delta, where 00 to 200 feet in depth. The Little North ɔutary of the Pembina river on the north. , flowing in a general southerly direction :mbina in section 24, T. 163, R. 58. It has ; from 200 feet on the north to 450 feet ority of cases these streams drain a strip wide on either side. (See Plates XXI

t which may well be briefly considered ıe different valleys which are mentioned

valleys are undoubtedly of post-glacial Tongue and Pembina rivers there may f many as to whether they are of post-ıpt to think of glacial erosion as such viously existing contours, that in sur-ıscribe all the minor features of ero-ial time. But in studying the various ned rivers one is struck by several ıt to a preglacial existence.

at length and in many cases exten- usually associate only with streams remember that geologically speaking time since the retreat of the conti- a valley the size of the Pembina eriod. Compare the length of the gorges which are known to have

existed only since glacial times and the latter sink into comparative insignificance. And the Pembina valley can not be properly called a gorge; true it has steep, often precipitous sides, but it also has a well developed flood plain and in many cases shows remarkably good evidences of terraces. All this is not compatible with our conception of streams of recent origin. (See Plate XXII, Fig. 2.)

A second and much more conclusive evidence in favor of their preglacial origin is this: In many places on all three rivers, where a section exposing the drift and underlying Cretaceous strata was obtained, the drift next to the Cretaceous was perfectly fresh and unaltered while the Cretaceous itself was very much decomposed but yet preserving its main characteristics such as bedding and cleavage, in fact having all the characteristics of strata decomposed in situ. This invariably would occur on the north bank of the stream and often more than half way down the actual depth of the valley, where naturally the surface would be protected from erosion by the southward moving glacier, the lower surface not being sufficiently flexible to conform to the steeply pitching surface without decrease in erosive power and thus leave the weathered surface intact ready to receive its mantle of drift.

This was specially well revealed in the fresh railroad cuts, examined in the fall of 1908, where the spur of the Northern Dakota Railway Company follows the Tongue river valley to the Cement mines.

Thus it would seem that the occurrance of undoubted fresh drift upon decomposed Cretaceous strata, well down the side of a valley is conclusive evidence of that valley's preglacial existance. It may be mentioned that every place where the glacier had a good opportunity of eroding, as in the Red River Valley, the Cretaceous, where found in contact with the drift, is fresh and unaltered.

The high upland rolling prairie, which includes the greater part of Cavalier county, and lies to the west of the Pembina Mountain is imperfectly drained. There are a large number of intermittent sloughs, which contain water during the wet seasons of the year. These sloughs are formed by the collection of surface water in the depressions of the undulating surface. In the spring, a series of these sloughs will often contain water enough so that they may form a connection with drainage. This is well shown by the series running through T. 161, R. 61, and T. 162, R. 62, and which drains

north into Rush Lake. The lake in T. 163, R. 60, and Rush Lake are further evidence of this imperfect drainage. In dry summer seasons they do not occupy more than one-half of the area indicated on the map; and the remaining part affords excellent hay land. In wet seasons, these lakes have outlets to the north into the Pembina river. The stream shown in T. 163, and 164, R. 64, has a shallow coulee and drains northward into the Pembina.

GENERAL GEOLOGY.

In this portion of the report, the relations of the district under consideration to the neighboring parts of the continent are discussed and thus the general relationship as well as the details of the district itself are presented. For this reason it has been found necessary to introduce material that is foreign to the immediate topic, but which throws light on the broader aspects of the geology of the area.

The Red River Valley is characterized by the lacustrine silts, clays, and beach deposits of glacial Lake Agassiz. But the formations underlying these deposits and exposed by deep well borings are also of interest. Deep wells at Humboldt, Minnesota, Grand Forks, and Grafton, North Dakota, and Rosenfeld, Manitoba, have shown that rocks representative of the Archean and Paleozoic eras underly these lacustrine deposits.

The crystalline rocks of the Archean, which are chiefly granites, gneisses and schists, constitute the foundation upon which rest the later sedimentary formations. The Archean was reached at 638 feet at Humboldt, Minnesota, at 903 feet at Grafton, and at 1,035 feet above sea level at Rosenfeld, Manitoba. This would show that the surface of the Archean had a dip to the west and north of about twenty feet to the mile. These rocks probably form a part of the great Archean area of Canada and the Lake Superior region.

The Paleozoic era is represented in this area by the Cambrian and Silurian formation as shown by well records. The only evidence of the occurrence of Cambrian strata is furnished by the record of the well at Grafton. Here the Archean is overlain by 288 feet of shales and sandstone which are believed to belong to the Cambrian. Beds belonging to this age are found associated with the Silurian farther north in Manitoba, south and west of

Fig. 1. View on Pembina river, showing the outcrops of Niobrara

Fig. 2. View from bridge on Pembina river, showing outcrops of upper beds at the plant of Mayo Brick & Tile Company. The steep part of t Niobrara; the lower shelving part is Benton.

Fig. 1. Exposure of Benton shale on Pembina river in section 36, Fremont to
This is the easternmost outcrop under the delta. Shows concentration of l
in stream.

Fig. 2. Typical exposure of Pierre shale. In northeast quarter section 15, North township. A concretionary hard layer is shown half way up the slope.

	Feet.
10. Glacial drift	15–20
9. Shale, black	
8. Clay band, yellow	
7. Shale, black	
6. Clay band, yellow, similar to No. 4	
5. Shale, similar to No. 3	12
4. Clay band, yellow, which becomes dark blue at a distance varying from one to two feet from the surface	
3. Shale, very dark, carbonaceous, which has marked petroleum oder and weathers into small fragments. Contains numerous seams highly stained by ferric oxide	15
2. Shale, calcareous, "cement rock"	6
1. Unexposed to waters edge	10

No. 2 of the above section resembles in every particular tl called "cement rock" mined on the Tongue river by the No Cement and Plaster Company. It breaks with a conchoidal ture, but has no regular cleavage along bedding planes, tl generally it is traversed by numerous fissures, mostly at right to the bedding. It resists the action of water but crumbles easily when dry. A marked feature is a strong odor of petr which is always found in connection with the fresh rock.

A sample collected from this outcrop yielded the followi sults upon chemical analysis.

	Per cent
Silicia	13.7
Alumina	5.3
Ferric iron	2.4
Calcium carbonate	64.2
Magnesia	0.7
Sulphur trioxide	0.7
Carbonaceous material	8.C

This is the southermost natural exposure of the Niobrara region. Half a mile to the south a well passed through pra the same succession of layers and seven or eight miles furthe or about four miles west of Edinburg a deep well struck tl brara after passing through 150 feet of Pierre shale.

No. 3 and succeeding yellow layers consist of a very r yellowish clay. It is very soft and free from grit, stron sembling cheese in its texture. Unlike most clay howeve absolutely devoid of plasticity, crumbling down into an i ent mass when moistened. When unweathered it is dark but on exposure to air turns very quickly to a yellow colo ably on account of the rapid oxidizing of the ferrous salt in contains. It tastes strongly of alum and analysis re

The workings of the cement company reveal very well acter of the cement rock at this place. One tunnel exten nine hundred feet into the face of the bluff and discloses t faults or slips whose strike is approximately north. They angle of about seventy-five degrees from the horizontal, ping west. They have finely developed fault planes and face where the slip has occurred is very smooth and These displacements show that at one time or another t been some slight disturbance, perhaps a slight folding w sequent faulting.

The different layers of cement rock vary widely in tion. They may show the following or even greater r chemical composition:

	Per ce
Calcium carbonate	35
Silicon dioxide	12
Ferric oxide	3
Aluminum trioxide	4
Magnesium carbonate	0
Sulphur trioxide	0.25–0

A remarkably uniform and fine-grained layer, at prese used for the manufacture of cement, has the following tion:

	Per ce
Calcium carbonate	64
Silicon dioxide	14
Alumina and ferric oxide	7
Magnesium carbonate	tr
Sulphur trioxide	0

This material when properly burned and ground makes which in comparison with the average Portland brands lea little to be desired. The material is easily mined, it break clean roof and floor, and requires comparatively little timb

Outcrop in the southeast quarter of section 11, T. 161,

		Feet.
7.	Unexposed to top of bluff	
6.	Shale	6
5.	Clay seam yellow	
4.	Shale, Pierre	10
3.	Unexposed	15
2.	Clay bands, yellow and black	6
1.	Shale, calcareous, "cement rock"	13

A mile east of the old McLean Post Office, on the sa as the above exposure, the black and yellow bands are ex a cut recently made in improving the roadway, on the no

of the creek. They are much decomposed but easily recognized upon examination, and are covered with about five feet of sand and soil.

Nearly five miles due north of this place, in the Pembina delta a deep well struck cement rock at a depth of sixty feet. About six miles south and one mile east of McLean cement rock was struck at thirty feet. This seems to show that the Niobrara exists quite generally under the drift and lacustrine deposits of the Red River Valley at some distance east of the escarpment.

Around McLean there is a large district which is copiously furnished with springs of pure sparkling water. These issue at the contact of the drift with the underlying Niobrara, which is hard and compact, being impervious to the water which sweeps along the upper surface of the gently eastward sloping Niobrara.

Outcrop on Little Pembina river in the southwest quarter of section 3, T. 162, R. 57.

		Feet.	Inches.
6.	Gravel and quite large glacial boulders	20	
5.	Clay band, yellow		2
4.	Shale, calcareous, "cement rock"	15	
3.	Clay seam, yellow		6
2.	Shale, calcareous, "cement rock"	80	
1.	Unexposed	40	

This section occurs on the east bank of the Little Pembina and is thought to be a part of the Pembina delta. The delta deposit, however, is very thin here in comparison with its thickness farther east. The delta ends toward the east in a high steep bluff locally known as the first mountain.

Outcrop on the Little Pembina in the northwest quarter of section 10, T. 162, R. 57.

		Feet.	Inches.
8.	Unexposed to top, gravel and sand		
7.	Clay bands, yellow and black	5	
6.	Clay band, black		9
5.	Clay band, yellow		2
4.	Shale, calcareous, "cement rock"	15	
3.	Clay seam, yellow		6
2.	Shale, calcareous, "cement rock"	75	
1.	Unexposed	35	

Outcrop on the Little Pembina, on north bank at the point where it turns north after leaving the escarpment, southeast quarter of section 22, T. 162, R. 57.

		Feet.
6.	Clay bands, yellow and black, much weathered and exposed under the overlying black loam	3
5.	Shale, calcareous, "cement rock"	15
4.	Clay seam, yellow	
3.	Shale, calcareous, "cement rock"	1½
2.	Clay seam, yellow	
1.	Shale, calcareous, "cement rock"	85

Section on Little Pembina in the southwest quarter of se
T. 162, R. 57.

		Feet.
8.	Unexposed	100
7.	Shale	30
6.	Clay band, yellow	
5.	Shale	30
4.	Clay bands, yellow and black	8
3.	Shale, calcareous, "cement rock"	18
2.	Clay band, yellow	
1.	Shale, calcareous, "cement rock"	35

Outcrop in the southwest quarter section 20, T. 162, R. 5

		Feet.
5.	Unexposed to top of bluff	
4.	Clay bands, yellow and black	6
3.	Shale, calcareous, "cement rock"	12
2.	Clay band, yellow	
1.	Shale, calcareous, "cement rock"	12

Where this section is exposed a four inch seam of c said to occur, but it could not be found. A six inch sean earthy hematite is reported in this vicinity and samples hematite were seen which seemed to be pure and in no way to the common grades of red ochre sold for paint. Loc used to some extent for paint. No definite information secured regarding the location of this deposit.

Outcrop on the Little Pembina in the southwest quarter c 19, T. 162, R. 57.

		Feet.
5.	Shale	150
4.	Clay band, yellow	
3.	Shale	35
2.	Clay bands, yellow and black	10
1.	Shale, calcareous, "cement rock"	10

In this exposure the thickness of the different layers distorted for the whole bank had the appearance of ha bodily toward the river. It is the last outcrop on the Little in which any of the Niobrara occurs. There are nume outcrops of Pierre for some miles farther up the river a some of its branches.

Section on the Pembina river in the southwest quarter 3, T. 163, R. 58.

the alumina. A considerable portion of the alumina is so warm water, which indicates the presence of free alumin phate or possibly alum.

As already noted, these bands preserve a very uniform cl throughout a very large area in North Dakota, and they a tend at least 250 miles northwestward in Canada. Their rence was noted in the Cretaceous outcrops in the Riding an mountains by V. J. Melsted, where they have exactly th characteristics as in the Pembina Mountains except that th better developed. The lowest layer noted in these norther crops was thirty inches thick and was overlain and underl a four-inch band of gritty limestone. The other bands wer four to six inches thick.

The thickness of the Pierre shale varies widely. It is g in the central part of the state, so far as known, and thi toward the east. This is probably due not so much to actu ning of the beds as to the greater erosion which the easte tion has suffered. The total thickness left near the edge escarpment in no case exceeds 450 to 500 feet, while tow west the formation attains a thickness of at least 1,000 feet

The Pierre is a gray to black shale, rather soft and fr grit. In weathering it breaks up into many small flakes harden when dry and remain fairly hard. It is pebbles of th which are so abundantly scattered through the soil of the part of the Red River Valley and which are commonly roneously called slate.

The Pierre formation is quite uniform throughout with ception of the lower forty to fifty feet in which are four layers of clay ironstone which on the weathered exposur well defined bands along the bluffs. This is especially w in the excellent exposures on the Park river half a mile Milton. The river here flows through a prairie region banks are for the most part devoid of any timber grow valley is deep and its sides are steep and in many places c afford a clean, well exposed section from top to bottom.

The composition of the shale varies somewhat from place in a horizontal section but probably more from to tom. A typical sample was collected on the well expo

Valley; but the small width of this channel indicates that th then flowing there, probably westward, was not larger t present Minnesota river. This and many other streams of size, flowing into the Cretaceous ocean as it spread to over the former land surface of Iowa, Minnesota and Manito tributed part of the detritus which formed the vast mass ments, probably averaging a quarter of a mile in depth, o most of its area. These beds could be supplied only by th sive denudation of the land areas both west and east of the (ous mediterranean sea.

The great disturbances of the region to the west during vation of the Cordilleran mountain ranges, since the Cretaceo iod, make it impossible to trace there the course of the larger s entering this sea. On the eastern half of the continent the pal drainage system, carrying its vast freight of detritus west Cretaceous ocean, is probably marked by the chain of grea from Ontario to Superior; the west end of which is close to border of the submerged belt. At that time, and onward t the Tertiary era much of this eastern land area appears to ha elevated at least three hundred feet above its present level, streams eroded the deep basins which are now occupied t lakes, but which then had a continuous westward descent.] probable also that other great tributaries may have flowed w and southward into the Cretaceous sea, bringing sediments from the areas of Hudson Bay, Lake Athabasca, Great Sl Great Bear lakes. Thus were accumulated in the great Cr sea of the interior the thick formations of the Great Plains

Since their elevation above the sea erosion has been sl constantly wearing away the Cretaceous rocks. When thes and lacustrine deposits were first raised to form land they h notonously flat surface, and they probably extended east, as seen, over the entire basin of the Red River of the North great lakes of Manitoba and west as far as the Rocky M The greater part of the present Cretaceous area, though e below its original surface, is flat, undulating or moderatel and constitutes a broad expanse of plains with very slo westward. But here and there isolated areas of much high as the Turtle Mountains, consist of remnants of horizonta ous strata which elsewhere have suffered denudation. T

tion of the Glacial period, with high elevation of all the n
part of this continent and of the glaciated northwestern por
Europe.[1]

At the time of the uplifting of the Great Plains near the
the Tertiary period this great base leveled region appears
stretched from the Rocky Mountains to the Archean hills
eastern border of Lake Agassiz, and to have included also
panse of flat or only moderately undulating country which
gradually from Lake Winnipeg and the upper part of the
river towards Hudson Bay. The Tertiary drainage of this
from the present sources of the Saskatchewan, Red and Rainy
to Hudson Bay and Strait, probably formed a great river f
through the Appalachian-Laurentide mountain belt in the deep
which is now submerged to form this strait, and empting in
Atlantic between Labrador and Cape Farewell. The depres
the lower part of this basin seems referable to the time of the
ation and departure of the Quaternary ice-sheet. Between th
tiary base leveling and this subsidence a widely extended epei
uplift of North Dakota intervened. To this period of late F
and early Quaternary elevation belong the erosion of the
of the Colorado and its tributaries, of the canyons on the sl
the Sierra Nevada, and much river channeling of the plain
the Rocky Mountains.

The eastern margin of these plains, which probably exter
before stated, over the whole area of Lake Agassiz, was then
ed to renewed erosion, removing the soft Cretaceous strata
width of a hundred miles or more and to a depth toward t
of several hundred feet. Previous to this new cycle of acti
by the streams, Riding and Duck mountains stood above the
level, like the Turtle Mountains and other isolated highe
farther west, and the maximum depth of the late stream-cu
which the trough of the Red River Valley and Lake Aga
formed is approximately measured by the height of the
Mountain escarpment, which rises 300 to 400 feet from its
its crest throughout an extent of about eighty miles. The
part of this erosion we must attribute to the probably long
elevation preceding, and finally at the climax producing,
sheet of the Glacial Period. So far as can be discerned, t

[1] Ann. Geol., Vol. VI., pp. 327-339, 396, Dec., 1890. Am. Jour. Sci.
XLI, pp. 33-52, Jan., 1891; Vol. XLVI, pp. 114-121, Aug., 1893.

The sample was weathered but was stained slightly along the seams, undoubtedly due to a small amount of oxide. It showed no sand on casual examination but a sm cent was revealed upon washing the dried sample.

A sample taken near the top of No. 3 of the section jus tioned showed the following composition:

	Per cen
Silicia	66.(
Alumina	8.3
Ferric oxide	3.9
Lime	1.4
Magnesia	2.8
Sulphur trioxide	.5
Alkalies combined	2.1

This sample was free from sand and very fine and compa represents a typical sample from near the top of the Pierr it is from shale of this composition that the black "gumb is produced.

Going north the next locality where the Pierre is well e is a short distance south of Union, where a small creek has narrow V-shaped valley. There are several good outcrops this stream. The following section occurring on the so quarter of section 25, T. 159, R. 57, is probably the best e

		Feet. I
4.	Glacial drift, yellow, and composed of rather sandy clay with large boulders. In places it rests directly on No. 3, out in others there is a layer of shale above No. 3, similar to No. 2	10–15
3.	Pyritic concretions, which near the surface are altered to limonite. These are very hard and resemble those found in the horizontal bands previously mentioned on the South Branch of Park river..	1
2.	Shale, medium dark, very fissile and all joints highly stained with iron	20
1.	Shale, dark, carbonaceous, breaking into rather large conchoidal fragments; has many cracks slightly stained with iron	4

North of Union, where the Great Northern Railway c deep ravine, there is a very good outcrop on the northeast of section 26, T. 159, R. 57, as shown in the following sectio

		Feet.
8.	Drift and soil	10
7.	Shale, similar to No. 5	10
6.	Concretionary nodules and shale highly stained by iron	1
5.	Shale, grayish, very fissile	18
4.	Concretions, similar to No. 2	
3.	Clay layer, dark yellowish; very soft and plastic, free from sand and grit. Shows joints and seams	

similar to shale but does not resemble clay which has resulted from alteration of shale	1	
2. Concretions, very hard and compact layer. Appears to be shale very highly impregnated with iron..		2
1. Shale, very similar to No. 1 in the previous section	6	

A very peculiar feature of this outcrop and one not found elsewhere in the Pierre formation is the one-foot layer of yellow clay, No. 3. It was easily traced for a mile along the side of the ravine and preserved the same thickness and general characteristics throughout that distance. It can hardly be referred to as an alteration product of the shale as it is overlain and underlain by unaltered shale. It is possible that it is a stratum which has been the source of springs of water percolating between the two different layers of shale, but more likely it is a small separate layer of the Pierre shale which originally differed from the rest in composition and character. It occurs between strata which differ radically in essential features and it may thus represent a transitional stage.

On the North Branch of Park river where it cuts through sections 4, 5, and 9, of T. 159, R. 57, there are numerous fine exposures of Pierre. The gorge is here deeper than at any other place along the river's course, and from a quarter to a half mile wide. A description by Warren Upham of an outcrop in this gorge will give a good idea of the lower part of the Pierre as it is exposed east of Milton.

"In these places the stream flowing at the base of the bluff removes the talus which in other places conceals its lower portion, and the section rises with cliff-like abruptness at an angle of sixty to seventy degrees.

"Excepting occasional thin beds the whole thickness of the section here exposed is a gray hard shale more or less sandy, divided into layers from an eighth of an inch to two or three inches thick, and much jointed as it crumbles down into small fragments on the weathered surface. Rarely a bed a few inches thick, having the general dull color, is harder and less jointed, owing to its cementation by carbonate of lime, and occasionally the ordinary shale is blackened by the deposition of iron rust and manganese oxide as films in the jointage seams, the thickness of the portions thus colored being usually only a few inches, but in one instance half way up the north bluff three or four feet. Gypsum was obseved only

in minute crystals in fissures coinciding with the beds o cation; and in the form of satin spar filling the mold fro some shell, usually *Inoceramus*, has been dissolved away.

"Fossils are very infrequent but by careful search *ovatus* and *Scaphites nodosus* Owen were found, each re by a single specimen; also numerous *Inoceramus* casts, mo *ceramus sagensis* Owen, besides casts and fragments o lamellibranchs, not yet identified; and the teeth of fishes ently *Pachyrhizodus latimentum* Cope and *Lamma mudg* a smaller species. The teeth occur somewhat plentifully markably hard layer, six inches to a foot thick, about fi above the stream. With them this layer contains softer l somewhat irregular shape from one third to three quarter inch in diameter of a light gray color inside with a greenisl ior, which are probably coprolites. The other fossils were f the shale fragments forming the talus and their place in the was not determined."[1]

The harder layers referred to above correspond to what h termed concretions in the previous paragraphs. They re only shale indurated with iron, but the layers are jointed manner that the loose blocks resemble regular concretions i Neither is this the result of metamorphic changes in t itself but has its origin with the deposition of the sha so-called "coprolites" above referred to were determined tered pyrite concretions. On weathering the somewhat pyrite had altered to copiapite.

Further up stream, north and northeast of the town o there are some fine Pierre shale outcrops differing in no respects from the ones already described. They are we from the wagon road north of Milton where it passes alon and crosses the gorge of the North Branch of the Park ri

For a distance of three or four miles north of the poi the above mentioned branch of the Park river leaves the escarpment, there are no natural outcrops of either I Niobrara. The escarpment here seems to be relatively lov ly the entire Pierre has been eroded and in several places tions reveal the drift lying directly on the Niobrara, whic fresh and unaltered immediately in contact with the d

[1]Monograph XXV, U. S. Geol. Survey, pp. 93.

highlands of Labrador, sending its ice mantle southwai Maritime Provinces, New England and the Middle St west as the Mississippi river. This is called the Lau Labradorean ice-sheet or glacier. A second centre wa west coast of Hudson Bay, and from this area the ice str ward in all directions, westward to the Rocky Mounta ward to the Arctic Ocean, eastward into Hudson Bay, through Manitoba into the Dakotas, Minnesota and I grand ice-sheet has been named the Keewatin glacier, Canadian district of that name. A third centre was forı Rocky Mountains of British Columbia, which for a d 1,200 miles was buried under a great ice-mantle that flow the northwestward and southwestward.

An ice-sheet similar to that of North America in t Period now covers the Antarctic lands, and another is s the interior of Greenland. The latter has been so fa that its slopes and altitudes may be compared with the a sheets of North America and Europe. In comparing and altitudes of the upper limits of glaciation on mo Maine, New Hampshire and New York, with those in we observe the remarkable contrast that the former sh ents only about half as steep as the latter. Apparently tions for outflow of the ice in the case of Greenland are s equally favorable with those which prevailed on our co the Glacial Period. The comparison therefore suggest present elevation of the glaciated portion of this contin bably much changed from that which it had during its glaciation. If the North American ice-sheet during its growth and culmination attained steep slopes and hig near its borders comparable with the Greenland ice, the glaciation on our mountains show that during the time lation of the ice and until it attained its maximum exten iated area was uplifted as a high continental plateau, wit principal topographic features of mountains, valleys a contour as in preglacial and post-glacial times, but ha outer 100 or 200 miles slopes of probably twenty to thir mile, descending from the plateau of the interior of the oped country to its margin.[1] Similar uplifting seems al affected the glaciated northwestern part of Europe, for

[1]The Ice Age in North America, p. 595.

ial lakes which attended the recession of the ice-sheet in the northern United States and in Canada, was due to the temporary damming of the waters of glacial melting and rains on areas where the land has a northward descent. While the ice-sheet was melting away from south to north on such a slope free drainage was prevented, and a lake was formed, overflowing across the lowest point of what is now the southern watershed of the basin. Many of these lakes were of small extent and short duration, being soon merged into larger glacial lakes by the continued retreat of the ice, or permitted to flow away where basins sloping northward are tributary to main river courses draining southward.

Five principal evidences of the former existence of glacial lakes are found, namely: 1. Their channels of outlet over the present watersheds. 2. Cliffs eroded along some portions of the shores by the lake waves. 3. Beach ridges of gravel and sand, often, in the larger glacial lakes extending continuously for long distances. 4. Delta deposits, mostly gravel and sand, formed by inflowing streams. 5. Fine sediments spread widely over the lacustrial area. Lake Agassiz has left all these marks of its presence.

The five or six distinct beaches that were formed at the southern end of Lake Agassiz during its outflow southward are represented in the northern part by seventeen separate shore-lines, which are marked by definite beach ridges. The individual beaches at the south, when traced northward, become double or triple, and the highest or Herman beach expands into seven successive shore-lines. The explanation of these changes of level is found in a differential uplifting of the lake basin, increasing in amount from south to north.

The departure of the ice-sheets which spread the drift formations over the northern part of North America, northwestern Europe, and Patagonia, was in each of these great and widely separated areas attended by a depression of the land. While each of these ice-sheets was melting away, the land which they covered was somewhat lower than now, and its coasts were partially submerged by the sea. These are the only extensive regions of the earth which have lately borne ice-sheets that have now melted, and it seems to be a reasonable inference that the vast weight of their burdens of ice was an important element in causing their subsidence. Since

It should be added, however, that the depth of the glacial erosion was probably nowhere so great as to change the principal and grander topographic features of the preglacial contour. The most important influence of glacial action upon the topography was usually the removal or partial wearing away of comparatively small projecting knobs, and the filling up of depressions and valleys, bringing the surface to a more uniform contour than before the ice invasion.

The thickness of the sheet of superficial deposits overlying the bed-rock upon the area of Lake Agassiz is shown by wells to vary from about 125 feet to 260 feet or more in Minnesota, commonly from 200 to 300 feet in North Dakota, and from 50 feet or less to 250 feet or more in Manitoba. Wells in North Dakota pass into the strata underlying the drift at the depth of 220 feet in Fargo, 250 feet in Casselton, 310 feet near Grandin and Kelso, and 298 feet at Grafton.

Till or boulder clay constitutes the greater part of the entire sheet of superficial deposits resting on the bed-rock, both within the area of Lake Agassiz and upon the adjoining country. But in some places this unmodified glacial drift is covered by modified drift or the stratified gravel, sand and clay deposited by streams which flowed from the ice during its melting, or by lacustrine and fluvial sediments. Fully half of the area of Lake Agassiz in Minnesota and North Dakota has a surface of till. Beneath the delta deposits of gravel and sand, and along the central portion of the Red River Valley, where the surface is commonly fine silt or clay, a sheet of till lies between these sediments and the bed-rock.

The till is the direct deposit of the ice-sheet, as is shown by its consisting of clay, sand, gravel and boulders, mingled indiscriminately in an unstratified mass, without assortment or transportation by water. Very finely pulverized rock, forming a stiff, compact, unctuous clay, is its principal ingredient, whether at great depths or at the surface. It has a dark, bluish-gray color, excepting in its upper portion, which is yellowish to a depth that varies from five to fifty feet, but most commonly between fifteen and thirty feet. This difference of color is due to the influence of air and water upon the iron contained in this deposit, changing it in the upper part of the till from protoxide combinations to hydrous sesquioxide. Another important difference in the till is that its upper portion is commonly softer and easily dug, while below there

from Breckenridge and McCauleyville to Winnipeg, wi on each side of the river varying from a few miles to twenty miles. Where the Red river has cut through thi ulation of till it forms Goose Rapids.

In North Dakota the ice barrier of Lake Agassiz durin cumulation of the Leaf Hills moraine is believed to hav to the northwest, extending upon the area of till along th side of the sand and silt delta which reaches from McCanr five miles south to Portland. The existence of this lar evidently due to drainage from the melting ice-sheet wit pendence on the aid of any of the present streams, havi deposited by a glacial river flowing southward from the Elk implies that north of it the ice front was deeply incised. entrant angle probably moved gradually toward the nor near Hatton to Larimore and McCanna and along the whol of the Elk and Golden Valleys, and the ice-lobes stretche ward on each side of the delta, but were like the angle undergoing change in their position by a steady or mostl mittent recession from south to north.

The islands of morainic till which rose above the sur Lake Agassiz at its highest stage along a distance of mo thirty miles east of the Elk and Golden valleys, between M and Edinburg, were accumulated during this time on th margin of the Minnesota ice-lobe. Their material and that beach ridges formed from their erosion were derived fr north and northeast, and contain scarcely any Cretaceou from the Pembina Mountain area. No glacial currents from even a few degrees west of north seem to have con immediately to the formation of this moraine, although earlier stages of the glaciation currents from the north-n mingled their drift with that from the northeast upon this

Recessional morainic accumulations of till and boulde dropped on the western side of the Minnesota ice-lobe du retreat across the Red River Valley, where it was rapidly back by the laving action of Lake Agassiz, between the chi of formation of the ninth and tenth or Leaf Hills and Itas aines. In this class may belong the remarkable profusion o ers found at a few points in Gilby township, (T. 153, R. of which is commonly called "The Island." Among oth

pieces. It is of a gray coler, and contains white specks of carbonate of lime. The uppermost part of the Niobrara is chalky in appearance, often carrying gypsum, iron concretions and thin layers impregnated with alum. The cement shales which are high in lime, burn white at low temperatures, and those which are much lower in lime cream colored, but none of these are of use in the manufacture of clay products.

Pierre. The Pierre forms the uppermost horizon of the Cretaceous shales, and underlies the entire east central part of the state, forming a belt probably a hundred miles wide north and south. It is for the most part covered with a thick deposit of glacial drift, so that it is only exposed where the larger streams have cut down into it. The best outcrops occur along the Pembina, Little Pembina and Tongue rivers, where these have worked back into the escarpment bordering the Red River Valley. Outcrops are also found on the Park, Forest and Turtle rivers. The Sheyenne and James rivers have also eroded through or into the Pierre shales. Along the Sheyenne they outcrop at many points from its source to points below Valley City. Good exposures occur along the James river and Pipestem creek near Jamestown and a few miles north. The Pierre thus not only underlies the central part of the state, but is exposed in many places, and is thus available for use.

In general the Pierre is quite uniform throughout its whole extent. It consists of a dark gray, blue, or black carbonaceous shale. It is fissile and weathers easily into thin plates. The shale is fine grained but contains a little very fine sand. It also contains many small iron concretions which weather out and are seen scattered around the base of an outcrop. This iron stains the clay brownish when weathered. Though high in iron, no samples of the Pierre are high enough in lime to give any effervescence with acid. Just what percentage of lime is present it is impossible to say, as all the samples were collected too late for a chemical analysis, but it is undoubtedly low.

About 300 feet of Pierre shales are exposed in the Pembina Mountain region. The lower part consists of a very fissile, dark gray to black carbonaceous shale. It weathers out into very thin small flakes. Scattered along the outcrop are seen many small iron nodules.

An examination of the shale exposed along the main Pembina river for two or three miles north of Mayo was made and a sample,

where stripping could be carried on and many places along the ravines where tunnels could be run in. Which method shall be pursued will depend upon circumstances surrounding each individual case.

The best method of mining is that used in mining coal, and known as the pillar and room system. A tunnel is first run in and rooms are worked off on both sides, leaving pillars large enough to support the weight of the roof. The main tunnel should be timbered with sets not more than four feet apart, two posts and a cap constituting a set. In the side entries less timbering is required. Ten feet between sets is safe if the roof is occasionally inspected for loose rocks, which should be timbered up to prevent caving. As a rule no lagging is required as the rock is hard, breaks clean, and does not crumble down much under action of the mine air.

Under normal conditions one pound of forty-five per cent dynamite should break loose sufficient rock to produce twenty barrels of finished cement. Of course, with inexperienced miners much more than this may be used, but it is not necessary. Timbers should be cut to measure and fitted outside the mine entry, as this is apt to be done in a slipshod manner inside the mine. The mine should be well drained by ditches leading to a sump in which the water should be kept well below the surface of the mine floor.

Burning. The burning constitutes probably the most important part in the whole process of cement manufacture. With a poor burn there will result poor cement, no matter how good the raw material may be. There are two types of kilns in use for burning natural cement, an intermittent kiln, and a continuous kiln. The intermittent kiln is practically going out of use. It resembles an ordinary lime kiln. The rock is piled on top of the grates and then the fire is built under it and kept burning until the whole mass above is sufficiently burned. Such a kiln is slow in operation and requires much fuel.

The continuous type now most commonly in use is a straight shaft kiln about ten feet in diameter and forty feet high. At the top it narrows down to seven or eight feet in diameter, this shape causing it to have a better draft. The lower part is lined with ordinary or low grade fire brick, while the top is lined with high grade fire brick. To start operations the kiln is filled with raw rock to within four or five feet of the top, and a fire is then started on top of this rock. When a good bed of fire has been secured

Underburned Cement.

NO GYPSUM.

P

7-day neat ....
28-day neat ....
7-day sand ....
28-day 3:1 sand ....
Initial set: fifteen minutes.
Final set: twenty minutes.
Fineness: 100 per cent through 100 mesh.
93 per cent through 200 mesh.
Normal consistency: 45 per cent of water for neat.
17 per cent of water for 3:1 sand.
Specific gravity: 2.6.
Normal pat: softened on boiling.

GYPSUM TWO PER CENT.

P(

7-day neat ....
28-day neat ....
7-day 3:1 sand ....
28-day 3:1 sand ....
Initial set: fifteen minutes.
Final se: twenty minutes.
Normal consistency: 45 per cent of water for neat.
17 per cent of water for 3:1 sand.

GYPSUM FOUR PER CENT.

7-day neat ....
28-day neat ....
7-day 3:1 sand ....
Initial set: twenty minutes.
Final set: thirty minutes.
Normal consistency: 45 per cent of water for neat.
17 per cent of water for 3:1 sand.

GYPSUM SEVEN PER CENT.

Po

7-day neat ....
28-day neat ....
Initial set: twenty minutes.
Final set: thirty minutes.
Normal pat: softened on boiling but was O. K. after 28
in water.

As previously stated the clinker from which this cement was soft, yellowish in color and very easily ground. Wl once through a disc mill it came out in a very fine floury is in all ways equal to the ordinary natural cements whi the market. On account of the bituminous matter in tl can be made with but very small fuel consumption and of the softness of the clinker the expense of grinding very low. For sand mortars it would be equal to lime in and would have many advantages on account of its hydra erties.

The proportion for the second mixture was deterr fifteen parts of chalk to one hundred parts of cement rocl

The cement rock and chalk were first passed through a er and then ground to the proper fineness in a small tube trouble was experienced in keeping the mixture from b the tube mill; but by introducing only a small amount of at a time and keeping a good charge of flint balls in the isfactory grind was obtainable. The materials after be were wetted and made up into round balls the size of a nut. These were dried preparatory to burning in the s cal kiln. The continuous method of burning previousl to in connection with burning of natural cement was account of the high point of fusibility of this clinker none through sufficiently burned the first time, but by passing the kiln a second time only a small amount of underburn remained. The underburned clinker was carefully sep the two kept separate during grinding. A small amour burned clinker was secured, but not in sufficient qua testing purposes.

UNDERBURNED CEMENT.

	F
24-hour neat	
7-day neat	
7-day 3:1 sand	

Initial set: ten minutes.
Final set: twenty-five minutes
Fineness: 93 per cent through 200 mesh.
Normal consistency: 35 per cent of water for neat.
13 per cent of water for 3:1 sand.
Specific gravity: 2.7.
Boiling test: pat disintegrated.

These were all the tests which were made on the ı portion. They show conclusively the necessity for a tho ing of the raw materials, even when they do not carry t high limits of lime. These tests along with those n underburned natural cement also show the excessive water necessary to bring an underburned free lime c a normal consistency. Also the specific gravity is very than on a normally burned cement.

GYPSUM TWO PER CENT.

	1
24-hour neat	
7-day neat	
7-day 3:1 sand	

Initial set: two hours.
Final set: about eight hours.
Boiling test: O. K.

GYPSUM THREE PER CENT.

	P
24-hour neat	not ha
7-day neat	

No sand tests made.
Boiling test: checked and warped.

From these tests is appears that the best amount of
add to this cement is one per cent, that producing abou
time of initial and final sets for ordinary Portland ceme
ments. The color of this cement was uniformly good.
cult to explain this, inasmuch as the raw materials cont
nearly the same amount of sulphur which so badly disc
natural cement. A possible explanation may be this: I
ural cement there was a considerable excess of clay ba
that account any sulphur not burned out of the cement w
a tendency to form a sulphate with the iron and alum
dark ferrous sulphate would discolor the cement upon e
the air or on long storage of the cement this ferrous sulpl
change to the ferric sulphate. In the ferric state the
action would not be so marked. This accounts for the
color in the natural briquettes upon exposure to the
the other hand, in the artificial Portland mixture the
be practically no excess of clay base. Therefore, any s
burned out would probably tend to combine with the lim
calcium sulphate which of course would produce no
color.

THE GEOLOGICAL HISTORY OF NORTH DAKOTA

BY

A. G. LEONARD

Carboniferous periods. The Devonian is marked by t
tion of the fishes, which were present in great numb
large size, and during the Carboniferous coal-forming
in great abundance and luxuriance.

It is possible from the study of the various characteri
rock formation to gain much information regarding the
under which that particular group of strata was formed.
from the observation of present day processes, that san
formed near the shores of sea or lake, where the coars
carried by streams is deposited. The finer debris, su
and clay, will remain longer in suspension and will be
before settling to the bottom at a distance from the sho
a clay rock or shale. Limestone, which is composed of
of sea animals, or of the fragments and calcareous m
from these shells, is formed only in clear water—fou
far from shore, where the conditions are favorable for
and accumulation of these limestone- forming organisr

Again, the fossils contained in the rocks tell whether
formed in fresh or salt water—whether they were lai
fresh water lakes or in the sea.

With these few words of introduction we pass to the co
of the geological history of that portion of the North
continent known today as North Dakota.

The oldest part of this continent, that which was the
raised above the sea, was a U-shaped land mass, the tw
the U enclosing Hudson Bay and comprising much of n
America. The nearest portion of this land area lay not
north and east of us, in northeastern Minnesota and

PALEOZOIC EVENTS.

At the beginning of the Paleozoic Era by far the g
of our continent, with the exception of the above lan
neath the sea and in this Paleozoic sea the rocks of
continent were forming off the shores. As portions of
floor were successively raised and made part of the orig
nental mass, the latter increased in size and extended
to the south, the east, and the west. Throughout all th
iods of time represented by the Paleozoic, North Dako
joining regions seem to have been under water. In thi
deposited the limestones, shales and sandstones of the
Ordovician, Silurian and Devonian, which outcrop a

where it is well shown. The Benton beds outcrop i only in the northeastern corner, in the Pembina Moun latter form a wooded escarpment bordering the Red R on the west for thirty or forty miles south of the interna dary. In this the rivers have cut deep valleys along shales of the Benton are well exposed. The outcro fined mostly to the Pembina and Little Pembina ri where these shales are covered by more recent strata and only from their being struck in wells.

Niobrara Beds. Following the Benton formation upon it is the Niobrara shale and chalk rock, named fro sive development along the Niobrara river near its ju the Missouri in Nebraska. The surface exposures o are likewise confined to the stream valleys of the Pem tain region, where the rivers have cut through the ove and exposed the Niobrara. This formation is of spec on account of its calcareous clay and cement rock, the in the manufacture of natural hydraulic cement.

During Niobrara time there lived in the Cretaceous region countless numbers of microscopic animals whi a calcareous shell. It is the minute shells of these F which, on the death of the organisms, fall to the botton and accumulate to form chalk. The beds found in Cava are not composed of pure chalk, since more or less cla with the calcareous shells, but the latter form a large rock. Some layers of the Niobrara formation have composition which makes them a natural cement rock the manufacture of high grade cement and they are us purpose.

Fossil fish are not uncommon in the strata of this age the roof of the Pembina Cement Company Mine has five feet. Other fossils which have been found are t of the strange toothed bird (Hesperornis), a species o and the great swimming reptile known as the Plesio latter being one of the rulers of the Cretaceous sea.

Certain calcareous beds outcropping along the She at Valley City probably belong to the Niobrara format

Pierre Shale. Next above the Niobrara lies the P named from Fort Pierre, South Dakota, in the vicinity covers a large area. This shale immediately underlies

drift over nearly one-half the state, covering most of the eastern half outside the Red River Valley. The rock is a black to a light bluish gray shale, very uniform in appearance over a large extent of country. There is an interesting occurrence of the Pierre shale on Little Beaver Creek in Bowman county, in the extreme southwestern corner of North Dakota, where it occupies a small area along the Montana line. Here the upper portion of the formation is exposed and it contains large numbers of calcareous concretions varying in size from several inches to five and six feet in diameter. These are very rich in fossils, about twenty species having been collected here, among them many beautiful ammonites with the mother-of-pearl sometimes perfectly preserved, besides the oyster and chambered nautilus.

Fox Hills Sandstone. The youngest and last marine formation to be laid down in the sea which covered this region during later Cretaceous times was the Fox Hills sandstone. This has a thickness of about 100 feet and is exposed at the surface at only a few points in North Dakota.

Rocks which probably belong to this formation occur overlying the Pierre shale in northwestern Bowman county, where they are seen along Little Beaver creek; they appear on the Cannon Ball river six miles above its mouth and also on Rice creek, a tributary of the Missouri river which enters it eight or ten miles north of the Cannon Ball river.

At the close of the Fox Hills epoch of the Cretaceous period the marine conditions, which had existed in North Dakota for many ages, came to an end through an elevation of the land and the withdrawal and the sea. This district has never again been invaded by the waters of the ocean.

Evidence has been found in the southwestern part of the state, along Little Beaver creek, that after the formation of the Fox Hills sandstone, the region was elevated above the sea and the land thus formed was subjected for a time to erosion. At several localities this old eroded land surface is shown and resting upon it are rocks much younger geologically than those immediately beneath,—rocks formed also under very different conditions, since they are fresh-water deposits and contain fossils quite unlike the marine beds of the Cretaceous. This old land surface separating the older beds below from the younger beds above is known as an unconformity.

FORT UNION BEDS.

These younger strata overlying the Pierre shale an sanstone cover the entire western half of North Dakota tute a formation with a thickness of 1,600 feet. In m this is the most important and interesting geologica in the state, for in it occur the lignite beds, while its cla have been sculptured into the picturesque badlands. years there has been some doubt as to the age of this of beds but recent discoveries and the many fossils coll the past few years have thrown much light on this. Th is now referred to the latest of the great time divis earth's history (the Cenozoic Era) and to the earliest s era. It is known as the Fort Union, a name derived f fort at the mouth of the Yellowstone, near the site of town of Buford.

During Fort Union time, then, western North Dakc with adjoining portions of Montana and Manitoba, w by a large fresh water lake in which the sediments wash rivers were deposited to form the beds of shale and Certain portions of this lake became silted up from time converted into marshes or swamps where vegetation uriantly as in the Great Dismal Swamp today. The plants as they died year after year and accumulated u where they were protected from decay, were in cou converted into the beds of lignite, so abundant in the formation.

Some of the coal beds are of great extent. One i extend twenty-five miles in one direction and twenty r other, with an area of at least 500 square miles and a from five to sixteen feet. Another bed of coal has thirty-six miles north and south and twenty-four mil west, and while its known area as shown from outcro 900 square miles, it undoubtedly had an extent of 1,0 square miles. The thickness of this coal bed ranged to fifteen feet and over.

The Fort Union formation is readily separated into sions by a marked difference in character and appea upper beds are composed of rather dark gray sandstones with many brown, ferruginous, sandy nodules and The middle division is formed of light ash gray and

the sides of every hill and butte, bear the marks of the last shower. They are grooved with countless tiny channels formed by the little rivulets of water which poured down the slopes. Each rivulet gathers up its load of detritus and carries it on to the main stream. The river has its numerous tributaries and these in turn have their branches which are ever working back into the land. And thus what was formerly a comparatively level plain, similar to that about Dickinson is now carved into the weird and picturesque badland topography which is described and figured in all text books of geology.

Beauty and variety are added to the landscape by the diversity of color. The colors are arranged in broad bands along the faces of the bluffs—gray, yellow, black and red of every shade and tint, together with browns and pinks. The banded and many hued bluffs, buttes, domes and pinnacles are a characteristic feature of the badlands and increase their attractiveness from a scenic point of view.

OLIGOCENE BEDS.

At several localities in the state there are remnants of a formation still younger than the Fort Union, and resting therefore upon the latter. This belongs to that division of the Cenozoic Era known as the Oligocene, and the beds of this age are found on top of Sentinel Butte, they form White Butte in southern Billings county, and occur in the "Little Badlands" of southwestern Stark county.

Sentinel Butte enjoys the distinction of being the highest point in North Dakota, having an elevation of 650 feet above the plain at its base, and 3,350 feet above sea level. Occupying thirty or forty acres on its summit there are beds of white marl and limestone about forty feet thick, which must have been formed in a fresh water lake covering a considerable area in the western part of the state during Oligocene time. The strata on top of the butte are merely the remnants of a once widespread formation which has undergone extensive erosion and has thus been very largely removed except at a few localities such as this which were favorable for its preservation. In the waters of this Oligocene lake lived large numbers of small fish whose remains have been perfectly preserved on the thin slabs of white limestone.

White Butte is so called from its chalky whiteness, though the rocks of which it is formed are not limestones but calcareous clay

and sand, together with a coarse conglomerate compo
worn pebbles of volcanic rock which must have bee
streams hundreds of miles from the Rocky Mounta
the Black Hills.

The Oligocene beds are here 300 feet thick and
Earl Douglass, of the Carnegie Museum of Pittsburg,
ago collected the bones of the three-toed horse (the
the modern horse) and the rhinoceros. The geologic
of the University contain the skull of an extinct cud-ch
mal from these same strata.

Rocks of this same age are also found in the so-calle
lands of southwestern Stark county and the beds here
the remains of many extinct mammals.

These Oligocene beds are thought to be in part l
as already stated, and in part river deposits. The lack
ity, the cross-bedding, and the coarseness of the mater
parts of the formation are probably the result of d
rivers, while other portions were apparently laid down
quiet waters of a lake. Whether the beds of the thre
kota Oligocene areas were deposited in one large lake
considerable portion of Billings and Stark counties,
they were accumulated in several small lakes, it is impo

The disappearance of the Oligocene lake or lakes w
by a long lapse of time during which no new rock strata
ed in this region but on the contrary erosion was active
throughout the entire area. The land surface was atta
forces which are ever at work to reduce it to sea le
water being the most effective of these agencies, and
dreds of feet of strata were swept away by the st
numerous high buttes which rise above the surround
and form conspicuous features of the landscape, bear
testimony to the enormous amount of erosion which
place, for they are formed of horizontal beds of cl
which were once continuous over the entire region, bu
almost wholly carried away through the work of run
Such buttes as Sentinel, Bullion, Black, Rainy and sco
are merely the remnants of these beds and can only be a
by the erosion and reduction of a land surface which
erly have been several hundred feet higher than the high
buttes. The thickness of strata thus removed over ext

in western North Dakota could not have been much less than 1,000 feet, and it may have been more. This included almost all of the Oligocene beds and some 700 feet and over from the upper portion of the Fort Union formation.

THE GLACIAL PERIOD.

At no time in its geological history has the state undergone more important, far-reaching or more significant changes than during the time just preceding the present or Human Period, that is, during the Glacial Period. The climate now changed to one of Arctic rigor and for some thousands of years it was like that of the polar regions. Immense glaciers or ice-sheets, comparable to those found today in Greenland and the Antarctic region, but many times larger, moved down from the north and buried all the northern part of North America under thousands of feet of ice. There were three centers of movement for these great continental glaciers, one east of Hudson Bay, one west of the same bay and the third in the Canadian Rockies. The Keewatin and Labrador ice-fields moved out to the north, south, east and west. South of Hudson Bay they united and invaded the United States as one. New England was completely buried by ice, as were portions of New York and Pennsylvania. It extended south to the Ohio river at Cincinnati, and to southern Illinois and Indiana. West of the Mississippi the line marking the limits of the glacier passes near St. Louis and Kansas City, then curves northward and follows in a general way the course of the Missouri river to Montana; here it turns north and crosses the international boundary a short distance east of the Rocky Mountains. All of North Dakota except several counties in the southwestern corner was covered by the ice-sheet and its surface features were profoundly modified by it, while its soils are largely of glacial origin, directly or indirectly.

When after some thousands of years the continental glacier withdrew it left behind a deposit of greater or less thickness which forms a mantle concealing the bed rock from view. This peculiar glacial deposit is known as drift and it is composed of clay, sand, gravel and boulders mingled together to form a heterogeneous mass. The chief constituent is commonly a stiff blue or gray clay through which are scattered numerous pebbles and boulders of granite or other igneous rock. One very noticeable feature of this boulder clay or till, as it is called, is that very many of the boulders and pebbles are unlike the bed-rock of the vicinity. They have

istic of terminal moraines. There are as many as eleven of these moraines in the eastern half of North Dakota and their presence adds much to the roughness of the surface. These hilly belts often form conspicuous topographic features and can be seen from a distance of many miles.

The outermost and the best developed of all these moraines is known as the Altamont moraine, which forms a conspicuous belt of irregular hill and hollows ten to fifteen miles wide. The margin of the ice-sheet must have remained stationary here for a long time to allow the rock debris carried by the glacier to accumulate in this great stretch of morainal hills. This Altamont moraine has been traced across the state from north to south; it traverses Ward county from northwest to southeast about thirty-five miles west of Minot, turns south through eastern Burleigh county, crosses northeastern Emmons and after making a loop to the east into Logan and McIntosh counties, again enters the southeastern corner of Emmons, whence it continues into South Dakota. The Northern Pacific railroad crosses the Altamont moraine between Driscoll and Sterling.

The drift outside is very little older in appearance than that inside the moraine, and is strikingly different from the Kansan as it appears farther south in Iowa and Kansas. For this reason it is believed to be Earlier Wisconsin, and the drift within the moraine is probably Later Wisconsin.

The continental ice-sheet is the cause of the wide-stretching, gently rolling to rough drift plain with its numerous lakes and imperfect drainage which occupies nearly two-thirds of the state. Its effects are everywhere apparent and unmistakable. Before its advent the area was undoubtedly more uneven than at present, since it was an old land surface which had been roughened by the long continued erosion of streams. The ice-sheet modified all this and tended to level up the region by wearing down the hills and ridges and filling the valleys with debris. Upon its retreat there was left the heavy mantle of drift which conceals from view the old preglacial surface. It is this drift which forms the rolling, and in places rough, plain stretching westward from the Red River Valley clear to the Montana line north of the Missouri, and extending fifty miles or more west and south of that river.

The broad, flat plain known as the Red River Valley was also formed through the agency of the ice-sheet. The valley consti-

THE BOTTINEAU GAS FIELD

BY

JOHN G. BARRY

THE BOTTINEAU GAS FIELI

BY JOHN G. BARRY.

During the past year and a half several discoveries gas in Bottineau county and eastern Ward county have siderable excitement. The first discovery was made at farm about nine and a half miles south of Westhope 1907, when gas was struck at a depth of 178 feet whil well for water. Since that time many wells have been gas in the same region and a number of them have been A preliminary investigation of the region was made ea tember, 1908. Since the time possible for this work wa ited, only the main facts in regard to the field were obtain

The wells drilled in the vicinity of the Parker farm pa the glacial covering and cut a gas bearing sand at dept from 154 to 176 feet. Four wells at this place have s flows of gas, while three others drilled to the north, tov hope, have been unsuccessful. A pressure exceeding 100 square inch and a flow of two million cubic feet per day for each of the successful wells. The Great Norther and Pipe Line Company, which has been carrying on at the Parker farm, has drilled a deep well in hope of deep seated body of gas. At the time of the visit to this deep well had reached a depth of 1,180 feet. An oi of the usual American type with a derrick built on the in use. (Plate XXIX). The boiler was fired with nearby well. The following strings of casing were in feet of 10-inch, 600 feet of 8-inch, and 995 feet of 6-inc ing from the surface. On September 11, 1908, this well following section:

	]
Soil	
Yellow clay and gravel	
Blue clay	
Gravel with sand below (no flow of gas)	
White slate	
Black sand seam (Pierre?)	
Soft blue shale (caving) (Pierre?)	

	Feet.	Inches.
Black "slate" (Pierre?)	50	
Blue shale (caving) (Pierre?)	205	
Yellow hard rock (limestone) (Niobrara?)	..	5
Blue shale	145	
Sandy shale	10	
Blue shale to bottom (Benton?)	320	
	1,180	

Oil seepage is reported in the common wells of this vicinity, but this is probably due to decomposing organic matter in the drift.

In the vicinity of Mohall there are two wells that have yielded gas. They are about seven miles west and north of the town, and about 26 miles west of the wells at Westhope. A generalized section of these wells is as follows:

	Feet
Yellow clay	20 to 25
Blue clay	200
Blue shale including streaks of black sand and coal (?)	70 to 80

Gas was reported to occur at a depth of 225 feet, at the junction of the blue clay and blue shale, and showed a pressure of 25 pounds per square inch. It was also claimed that further drillings gave gas at 340 and 470 feet, but this was due probably to loose casing with gas leaking down and around the bottom from the occurrence at 225 feet.

Since the visit to this region gas has been reported as having been struck at the following places: Maxbass, sixteen miles southwest of Westhope; Lansford, ten miles southeast of Mohall; and at the McCaslin farm, fourteen miles southwest of Mohall, and five miles west of the Parker farm, at a depth of 200 feet.

The sand in which the gas is found varies in thickness, in most cases, from 16 to 20 feet. It is medium fine grained, rounded, and of a greenish black color, due to an admixture of decomposing carbonaceous matter.

An analysis of the gas made by Professor E. J. Babcock, of the University of North Dakota, shows the following results:

	Per cent
Hydrogen	0.5
Methane	82.7
Ethylene and other illuminants	0.2
Carbon monoxide	1.2
Oxygen	3.0
Nitrogen	12.4

B. T. U. (calculated) 886 per cubic foot.
The oxygen and nitrogen are probably in the form of air.

Boring for natural gas nine miles south of Westhope, Bottineau coun
The boiler is fired by gas.

ious to the advent of the ice-sheet. Considering the Coteau du Missouri, and the Souris and Sheyenne riv onable to suppose that previous to glacial time there la and east of the Coteau a principal drainage area northwest-southeast course, and which probably di south and east.

Whether this drainage was occupied by a freely or by a large lake is not known. It is certainly reasc pose that there was deposited throughout the region a amount of detrital material with an admixture of or probably of vegetable origin. Upon the advent of part of this detrital material was no doubt eroded, bu could easily be covered by the relatively thick anc drift deposit. Upon the decomposition of the organi preglacial debris would act as an excellent gas res occurrence of this gas-bearing sand over so wide an the belief that this preglacial drainage channel was cupied for a time by a lake.

Another possible source for the gas is the organic r shales underlying the drift and gas-bearing sand. T have formed in the shales and collected in the overlyir

GOOD ROADS AND ROAD MATE

BY

W. H. CLARK

the reason why a longer haul is not profitable unless
transported be of greater than ordinary value as comp
usual product carried.

$1.25 will haul a ton	C
5 miles on a common road	
12½ to 15 miles on a well made road	
25 miles on a trolley road	
250 miles on a steam road	
1,000 miles on a steamship	

Stated briefly, the economies effected by good roads a
1. Reduction of the number of horses kept for haul
duction of wear and tear on horses. 3. Saving of
wagons and harnesses. Considering the first of thes
there were 314,493 horses in North Dakota. Good r
mean that this number could be decreased one-fourth.
seen that a large saving would be effected. Farmers
need to keep more than the usual number required for
work on the farm. In addition to the hauling done dire
farmers themselves, there is a large amount done by
freighters, ranchers and others who keep horses solely
pally for the purpose of hauling on the roads and they
tainly require fewer horses if the roads were impro
load which can be drawn by a horse depends upon the gra
surface of the road. The following table shows the relat
of horses necessary to pull an equal weight on various
faces:

Surface	Num
Iron rails	
Macadam	
Earth	
Sand	

Another way in which good roads will increase the
pacity of a horse is in the fact that much lighter wa
be used than are now required to withstand the jars
of our bad roads, and more of the horse work would
into hauling the load and less into merely hauling the d
of the wagon.

Secondly, the wear and tear on the horses is a very s
to farmers, both by reducing the life service of the anim
by increasing the necessary food. Figures on this poi
difficult to make accurately, but everyone having the car
will recognize that the saving will be considerable.

of Lake Agassiz contain all the road surfacing material for that part of the Red River Valley which lies in North Dakota. The beaches of themselves form a natural highway, no surfacing is required, and the grade in passing northward is only two hundred feet in three hundred miles, or two-thirds of a foot per mile. Practically no stone is found throughout this entire area, except the gravel of the beaches.

The beaches, which are approximately parallel, vary in number from six to fifteen, and occupy a strip one to six townships wide. They include an area of at least four thousand square miles. All of the roads in this area are so favorably located that they can be cheaply surfaced. Not all the material in these beaches is suitable for road surfacing, but there is an abundance of excellent gravel. At the southern end of Lake Agassiz, where the shore lines enter North Dakota, there is a delta of large area, formed by the Sheyenne river. The surface from a depth of from fifteen to forty feet is composed of delta sand and gravel. It is a plain sloping gently eastward and crossed by the Herman and Norcross shorelines, and in part by the Tintah and Campbell shores on its eastern and southeastern border. The front of this delta begins at the Herman beach in the south tier of townships in Cass county. From the Maple river it extends eastward eight miles, passing Leonard, and thence southeasterly twenty-five miles. Its greatest length fifty miles from southeast to northwest and its greatest width is thirty miles. It covers an area of 800 square miles. Large tracts of this delta are channeled by the winds and heaped up in dunes which rise to a height of twenty-five to one hundred feet or more. Most of the delta is composed on the surface of coarse sand, though gravel deposits are found in places. The four beaches which border this delta, three on the east and one on the west, furnish an abundance of gravel for road surfacing material. As this area is crossed by five railroads, the sand and gravel are readily available.

The road problems which exist on this delta are the opposite of those found in adjacent parts of the Red River Valley. Here the rainfall readily soaks into the soil leaving it dry and sandy. The cheapest method of preparing such a road surface for traffic would consist in surfacing it from the gravel beds. On the other hand the sand and gravel of the delta would be serviceable in preparing the roads of the muddy valley to the east. It has been

WINDS

Winds, which tend to sweep away all the fine mater by traffic, have little effect on valley roads. Their g is noticeable in the glaciated part of the state where a sandy nature. This fine material has a cementin allowed to wash into the surface of the road. Good has long been known to road builders to be one of th tant properties possessed by a satisfactory road stone material of a road binds well, it protects the foundatio from soaking, and withstands better the action of rain. Cementing power is a very important and valu of any road material.

The soil of the river valleys of North Dakota bond is easily recognized from the appearance of a dry r badly cut up by wagon wheels when wet. After baki the uneven edges are cemented powerfully enough heavily loaded wagon. If such a road surface were fore drying it is seen that while dry it would prove a way. Then, again, if the natural surface can be m prevent soaking and capillary action, the road buildi river valleys is practically solved.

The soil in the glaciated area does not bind so we the river valleys, but containing a large proportion of on the whole better than that of the valleys. Great cha perature are characteristic of the whole state. The r and thawing will always be an important disintegratin sened only when water is kept from the surface and f the road.

SOME RULES OF ROAD BUILDING.

While it is true that each road officer knows best t which prevail in his own community, there are some applicable to all places.

First, what shall be the cross-section profile. From ter it should rise from one to three inches per foot, de other conditions, An arc of a circle is often used, a good form, but on the whole a curve more convex center than toward the sides is best. If there is no grad does not need much crown. The crown should inc grade increases. On a level road, the water is cast angles from the center of the road. Now if the gr

STATE

Geological Survey

Of North Dakota

Sixth Biennial Report

A. G. LEONARD, Ph. D., State Geologist

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c.

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GEOLOGICAL CORPS

A. G. LEONARD .... Sta

HOWARD E. SIMPSON .... Assistant Sta

E. J. BABCOCK ....

E. F. CHANDLER .... H

G. F. RUEDIGER ....Composition of Undergro

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R. T. YOUNG ....

T. R. ATKINSON ....Consulti

W. H. CLARK
R. L. SUTHERLAND
W. R. HOLGATE
W. H. GREENLEAF
F. B. FARROW
............................Fiel

[redacted]

since the State Survey has had no money with which to cooperate. Many of the states realize the great value and usefulness of these topographic maps and by appropriating large sums of money for the work are cooperating with the Federal Survey. The latter organization does all the work of preparing the maps and publishing them, all it asks of the states being that they bear half the expense of the field work. The United States Geological Survey agrees, so far as possible, to put in a dollar for every dollar contributed by the state. The State Survey should have an appropriation large enough so that several thousand dollars could be expended for topographic mapping.

The State Geological Survey now has in preparation a geologic map of North Dakota which will appear in the next biennial report.

Respectfully submitted.

A. G. LEONARD,
State Geologist.

GEOLOGY OF SOUTH-CENTRAL NORTH

by

A. G. LEONARD.

CONTENTS

measured along the channel of 94 miles. The H
fall of six feet per mile along the general cou
between a point ten miles south of Richardton
but below the mouth of the Big Muddy the rive
which probably does not exceed four feet per
The fall of the Cannon Ball River between Mot
is five feet per mile of valley, and below Stevens
per mile. The valley of the Big Muddy has a g
feet per mile.

TOPOGRAPHY.

The region presents two chief topographic t
plain with its rolling to rough surface, and the m
lowlands along the streams. In addition there
areas of badlands along the Cannon Ball and othe

The Upland.—The elevation of this upland v
to 2,400 feet above sea level. The streams have
the surface of the plain and have so thoroughly d
much of the area that only scattered remnants
plateau remain to bear witness to the extensive a
ued erosion. The largest of these is in southea
and southwestern Kidder counties, where there
outwash plain formed by the waters of the melting
the Altamont moraine was being heaped up. Mu
washed out from the ice border and spread over
many miles beyond to form the outwash plain, w
gone but slight erosion. It has an elevation of
1,800 feet and over above sea level, and contains
depressions occupied by lakes and marshes, amo
Lake is by far the largest, with a length of abou
the vicinity of Hazelton, in northern Emmons Cou
has an elevation of at least 2,000 feet. West c
River in Morton County many upland areas l
ranging from 2,300 to 2,400 feet above sea leve
only a few miles back from the Missouri, as in t
south of Little Heart River.

Rising from 100 to 200 feet and more abo
level of the upland plain are many buttes, whic
uous topographic features of the region. Among
Buttes, Twin, Coffin, Mitchell, Dogtooth, Little
and Crown buttes. A number are capped with
sandstone, which has protected the softer rocks b
have small summits and are cone-shaped.

In some places the upland ends abruptly in
which overlooks a lower plain or the valley lowl
escarpment is found five to six miles southwest of
in the northern part of T. 137 N., R. 87 W., and t
corner of T. 138 N., R. 87 W. Standing on the e

brush and timber. The flood plain has an ele 1,580 and 1,650 feet above sea level.

A terrace 45 feet above the normal water occurs at several points in the Missouri valley. is built upon this terrace, and it appears betwee Northern Pacific bridge. The main wagon roa traverses this terrace and the Fort itself is loca tween this upper terrace and the river there is six feet above the flood plain, or 21 feet above of the river. Livona, in northwestern Emmons C on a well-developed terrace which extends for th along the valley, with an elevation of 60 feet ab and an average width of about one-half mile. of the river for some miles below the mouth of the "River Road" to Cannon Ball Post Office developed terrace about 50 feet above the ordinar level. Traces of still others are found at inte valley. These terraces are composed in part o sandstones in which the valley has been eroded, gravel, sand and river silt deposited on this bed r

West of Sibley Island, five miles south of I defined depression representing the old channel River, follows around near the base of the bluffs road traverses a higher portion of the valley botto the abandoned and present channels.

The Heart River has cut a valley varying in from 150 to 250 feet in depth and averaging thr mile in width. That portion which has been eroc sandstone of the Lance formation is a narrow go steep cliffs, presenting a marked contrast to the and below, with their more gentle slopes and grea narrow sandstone gorge extends down the river f five or six miles below the bridge on the Glen Ull Then the black shales appear beneath the massiv valley grows wider, and slipping or slumping o taken place on a large scale. Great masses ha and slid down to the bottom of the valley, and f these extensive landslides form a very conspicuou

Terraces of gravel and sand appear at many valley, and are particularly prominent along the the Heart. In this portion the upper is about 1 lower 70 feet above the river. The lower terr well shown on the south side of the valley thre Mandan, where it has a width of nearly one-ha followed for over a mile by the wagon road. Th which has undergone considerable erosion, app Heart River south of Mandan. Near the bridge o

Leipzig road three terraces occur along the valley, these being 20, 31, and 83 feet respectively above the river.

Another noticeable feature of the Heart valley, particularly for several miles above the mouth of the Big Muddy, is the large number of alluvial fans. These are found at the mouths of short ravines and gullies, where the sand and gravel have been spread out by the streams which formed them. Many of the fans were built long ago, and are now grassed over, with good sized trees growing on them or in the ravines from which the material was washed. Others were formed only recently, as shown by their fresh appearance.

Old Valley of Heart River. The Heart River has not always emptied into the Missouri at Mandan, as at present, but was formerly a tributary of the Cannon Ball River. Instead of making the sharp bend seven miles north of Flasher, and flowing north and east from that point, it continued its southeasterly course in a valley now occupied by the lower portion of Louse Creek and a tributary of the latter from the north. Where the old valley leaves the Heart it forms a broad, well marked depression from one to two miles wide corresponding in size to that of the present river. The bottom of this depression rises gradually for a distance of about two miles south of the sharp bend of the Heart. and after attaining an elevation of 125 feet above the latter river it descends gently to the south, thus forming a low divide separating the drainage of Louse Creek from that of the Heart. The bluffs, bordering this abandoned valley on the east and northeast are continuous with those along the present Heart valley and rise 270 feet above the river, or about 150 feet above the old valley bottom at its highest point. When the Heart River followed this course it flowed diagonally across T. 135 N., R. 84 W., and T. 134 N., R. 83 W., and joined the Cannon Ball River in Sec. 36, T. 134 N., R. 82 W. For a distance of sixteen miles Louse Creek and its tributary now follow this valley and the stream formed by the confluence of Louse and Dogtooth creeks flows in it four miles before entering the Cannon Ball. A small northward flowing stream tributary to the Heart now occupies the northern end of the old valley.

It is evident from the preceding that at the time the Heart River had its course to the southeast into the Cannon Ball it flowed in a valley whose bottom was over 100 feet above that of to-day. Since the river was diverted to its present course it has eroded its valley 125 feet deeper than it was formerly.

What, then, is the cause of the sharp bend of the Heart and the diversion of its waters to the northeast into the Missouri? The most probable explanation is that we have here a case of stream piracy, or the capture of one stream by another,

a process by no means uncommon. The capture been made by a short and vigorous tributary River which entered the latter stream at Manda the same course as the lower Heart of to-day. and having a shorter course to the Missouri it h than the Heart, and on account of its swifter cur to erode its valley faster than that river. The st increased in length until the divide separating it was cut through by this northward flowing t Missouri, the Heart River was captured and its into this new channel. The Heart River was advantage compared with its rival owing to th Cannon Ball River into which it flowed was f valley, for over ten miles above its mouth, in sandstone, which is much less easily eroded than in which the rival stream was cutting its val Heart could not deepen its valley any faster th Ball River, the more vigorous stream on the no ditional advantage.

The valley of the Cannon Ball, like the vall souri and Heart rivers, forms a very marked top of the region. At Shields it has an average wi and varies from 100 to 200 feet in depth. For s the mouth of Dogtooth Creek the valley is bro tensive alluvial plain and broad terraces 20 to 4 river. On the other hand, that portion which is e Hills sandstone forms a narrow gorge with near and having a depth of 80 to 100 feet. Extendin side of this gorge-like valley is a broad gentl plain or terrace several miles wide. Rising fro low bluffs with gentle slopes, evidently the sid valley of the Cannon Ball before it had comme channel in the Fox Hills sandstone. The top c corresponds to the surface of this terrace, and the owes its origin to the more resistant character compared with the softer shales and sandston formation. The inner gorge has been cut in th the broad outer valley was eroded in the overl The high terrace marking the former valley b with numerous glacial boulders, showing that a valley is preglacial, and it is not improbable that inner gorge was eroded before the ice invasion.

At Mott the Cannon Ball River flows in a tively shallow valley with gently sloping sides, a and several low terraces. Cedar Creek, or the S Cannon Ball River has a valley similar in charac At Stowers, several miles above the Morton C

are four terraces with elevations of 13, 17, 35, and 75 feet respectively above river level.

Big Muddy Creek has a notably broad and well graded valley, considering the length and volume of the stream which now flows in it. The flat alluvial bottom averaging half a mile wide affords a natural grade for the Northern Pacific Railroad from Almont nearly to Antelope, or a distance of nearly 40 miles. The valley between Almont and Hebron has a gradient of seven feet per mile. In like manner the Mott extension of the Northen Pacific follows the valley of Louse Creek for a distance of nearly 30 miles, the average gradient here being fifteen feet per mile.

Badlands. Rough badland areas occur along some of the steam valleys of the region. One of the most extensive is on the Cannon Ball River in the vicinity of Stebbins, where the bare clay slopes and fantastic erosion features characteristic of the badlands are well shown. These are also found along the lower courses of Dogtooth and Louse creeks, and in places along the Big Muddy. As in the case of the badlands occurring elsewhere, these are formed chiefly through the agency of rain and stream erosion acting on shales and soft sandstones, which are carved into a great variety of buttes, mesas, domes and pinnacles whose bare clay slopes expose the strata composing them.

THE LITTLE HEART BASIN AND ITS MORAINES

The drainage basin of the Little Heart River presents many features of special interest which are due largely to the action of the continental ice sheet which covered the region during the Glacial Period. Below its confluence with the Southeast Branch, about ten miles above the mouth of the Little Heart, the river has a comparatively narrow and deep valley bordered by steep slopes. Above the confluence its valley is broad, with relatively gentle slopes, and included in it are the Little Heart Flats which extend east and west a distance of eight or nine miles, with a width of two to three miles. They comprise not only the alluvial plain of Little Heart River, which is of small extent, but also the broad valley bottoms of the Southeast Branch and South Branch.

The notable change in the character of the valley of the Little Heart River, shown in its greater width and its broad flats, is due to an ice lobe of the continental glacier which occupied this drainage basin during the Glacial Period. This lobe formed the belt of morainic hills which nearly encircles the valley plain and deposited more or less drift in the preglacial valleys of the Little Heart and its tributaries. As it melted, the waters flowing from it deposited much outwash silt, building the valley trains of the South and Southeast branches, and the broad plain of which the Little Heart Flats form a part. (Plate II, Figs. 1 and 2.)

Fig. 1. The broad flat of the Southwest Branch of Little He
of glacial outwash silt. Morainic hills show back of the fou

Fig. 2. Morainic hills stretching across the valley of the Sou
Little Heart River, Morton County.

That a considerable thickness of silt was depos
the fact that the divide which must at one tim
the upper valleys of the two branches was ob
filling up of the valleys. A belt of low mor
above the plain of the valley train is all that to
headwaters of the Southeast Branch from tho
Branch, and forms the ill-defined divide between
T. 136 N., R. 81 W.

A number of partially buried morainic hill
plain formed by the valley train of the Southeast
them just appearing above the level floor of the va
rising from the sea. (Plate III, Figs. 1 and 2.)
bear a very definite relation to the morainic hills
flats, sloping away from the moraine with a gr
relatively steep near the hills and becomes mor
away.

The Southeast Branch winds about over its
the morainic hills in a shallow V-shaped trench
depth in its upper portion. The South Branch fl
a trench even shallower and more poorly define

Though the moraines do not form a conspic
the Little Heart basin they are nevertheless wel
typical drift hills. They are perhaps best show
of the Southeast Branch where the moraines
bottom at several points, and also occur about
the base of the slopes. In the south half of Se
R. 81 W., the morainic belt crosses the uppe
Southeast Branch, some of the hills resting on th
the valley, and others rising from the flat. Abo
the valley is narrow, with almost no flood pla
the morainic belt the valley train is two-thirds
The drift hills shut in the upper valley so that t
cannot be seen, and the creek winds about amon
rise 20 to 40 feet above the surrounding surfa
Figs. 1 and 2.)

The morainic belt of boulder covered hills
tinues unbroken along the south side of the vall
Branch for a distance of about twelve miles.
well developed in Secs. 31 and 32, T. 136 N., R.
hills as usual occur near the base of the slope.
fields extend up to the moraine and end here
becomes too rocky and the slopes too steep for
moraine crosses the upper valley of the South
is completely shut in by the hills, near the n
ship line. The road leading north from the s
of T. 136 N., R. 81 W. passes between two p
hills, one pair on the south and the other on the

creek, and between a third pair just north of the forks of the road.

The morainic hills are also found on the north side of the broad valley of the South Branch, where they extend as far west and north as Sec. 23, T. 136 N., R. 82 W. The road along the north line of Sec. 32, T. 136 N., R. 81 W. leads over a typical morainic belt thickly strewn with boulders and lying on the slope 50 feet and over above the valley plain The moraine continues around to the west side of the valley of the Southeast Branch and extends north along the slope as far as the deep ravine near the north line of Sec. 20, T. 136 N., R. 81 W. Beyond this point no drift hills were observed.

On the east side of the valley there are few morainic hills north of the center of Sec. 21, T. 136 N., R. 81 W. A cluster of them occurs about the house on the north line of Sec. 28, where they lie in the valley and cover some 40 acres. The moraine is here nearly half a mile wide and extends a short distance up the slope. South of this point it is broken by the deep ravine in Secs. 33 and 34, T. 136 N., R. 81 W, but in the eastern part of Sec. 34 and in Sec. 3, T. 135 N., R 81 W. a wide belt of irregular hills is present, their sides thickly covered with boulders.

In addition to the scattered drift hills which rise above the valley plain there are three clearly defined moraines crossing the valley bottom of the Southeast Branch, all of them having a northeast-southwest trend. One extends from the Harm place in the SW 1/4 of Sec. 4, T. 135 N., R. 81 W. across to the northeast corner of the same section; (Plate II, Figs. 1 and 2.) A second crosses the valley in the west half of Sec. 33, T. 136 N., R. 81 W. The creek has cut its post-glacial valley through both these moraines. The third moraine, which forms the divide between the two branches of the Little Heart river, is in the northwest corner of Sec. 32, T. 136 N., R. 81 W. Several kettle holes, so characteristic of moraines, are here found among the hills.

The soil of these drift hills is too stony to cultivate, and the wheat fields of the plain extend only to their base, so that the knolls with their many boulders present a striking contrast to the surrounding grain fields.

The morainic hills are also present on the north side of the main valley of the Little Heart, where they are found on the slope some distance above the flats, in one place as much as 150 feet. The hummocky knolls and hills, thickly strewn with boulders, extend from the Mandan-Flasher road east as far as Sec. 28, T. 137 N., R. 81 W. Several morainic hills also appear east of the Little Heart, in the east half of Sec. 28. The hill in the NW. 1/4 of Sec. 30, of the same township and range, is formed in part at least of drift, and has on top several low,

irregular knolls with great numbers of large bou

Rising out of the valley plain, in Secs. 33 ar R. 82 W., is an area of morainic hills which rises above the Little Heart Flats surrounding it or rough, hummocky surface has many low knolls w paved with boulders. This area has a length e one and a half miles, and a width of about one ern end is crossed by the main wagon road fr Flasher.

These moraines of the Little Heart Basin ap ginal accumulations of drift about an ice lobe the basin for a considerable period after the con had retreated some distance from its extreme in this region. The limit was 40 or 50 miles f indicated by the presence of numerous glacial b little or no till or boulder clay is now found we Heart area. The ice was several hundred fe the drainage basin of the Little Heart than over t upland, and therefore probably occupied this d long after it had disappeared from the highlan glacier began its final retreat from this basin the waters flowing from the melting ice formed the the South and Southeast branches, and also th flats of the Little Heart.

Apple Creek has a broad and comparatively with gently sloping sides. At the time the conti was forming the Altamont moraine, which is Northern Pacific Railroad between Driscoll and tion of the drainage of the melting ice was thro which at that time was doubtless much deeper th dences of this are furnished by the well at the P another two miles south of McKenzie. Both passed through 200 feet of silt and struck a bed o ers which rested on several feet of sand mingled of lignite. This deep preglacial valley was fille thickness of silt washed out from the melting Creek must at that time have been a stream ma than at present. Several outcrops of sand-ton along the creek in the southeastern corner of T. 1 are probably on the south side of this old pregla some places a terrace is present 45 feet above the portion of it at least being composed of gravel and

The depressions in the vicinity of Menoken a to the irregular deposition of the outwash materi raine. The long narrow one extending southeas part of a large marshy tract in which one branch has its source. Long Lake also occupies such a d outwash plain.

deposited in their present position by the gla could scarcely have reached this location if the eroded since the disappearence of the ice. Two Sugar Loaf Butte are other hills in the valley, a number of good sized boulders. Again, less north of Mandan, in the south ½ of section 23, line of the Northern Pacific Railroad passes thr terrace 55 feet above the Missouri River. Twel coarse stratified gravel and sand are here seen uneven eroded surface of the Cretaceous shale cut; mixed with the gravel are many boulders, so and three feet in diameter, and resting almost shales. The base of the gravel at its lowest pc feet above the river. These glacial materials we posited in the valley of the Missouri during th ice sheet was melting and retreating northward of their deposition the river had lowered its v at least 35 feet of the present river level.

LIST OF ELEVATIONS

The elevation above sea level of many points i given in the following list:

Almont ....
Antelope ....
Arnold ....
Bessoba ....
Birdsell ....
Bismarck ....
Bismarck, Missouri River, low water ....
Bismarck, Missouri River, high water ....
Blue Grass ....
Burt ....
Carson ....
Crystal Springs ....
Curlew ....
Dawson ....
Driscoll ....
Eagles Nest ....
Elgir ....
Flasher ....
Fort Yates ....
Gall ....
Glen Ullin ....
Hague ....
Hazelton ....
Hebron ....
Judson ....
Knife River ....
Kurtz ....
Lark ....
Lawther ....
Linton ....
Little Heart Butte ....
Louse Creek ....
Lyons ....

varying in size from a few inches to six a
eter. Some of these concretions are rich i
are characteristic of the upper part of th
are barren of fossils. Many are cut by
veins which are commonly lighter colored

FOX HILLS SANDSTONE

The Fox Hills sandstone is the most
formations of the Great Plains region. A
the materials composing it the sea disappe
now traveresd by the upper Missouri Riv
never again been covered by it. As sho
sandstone is found along the Missouri Riv
Fort Rice, about eight miles above the mou
river; it extends up the latter stream a d
teen miles, and on Beaver Creek is found
Linton.

At the mouth of Beaver Creek the top
an elevation of approximately 1,735 feet abc
150 feet above the Missouri River. The s
north at the rate of about six feet per mile,
three feet per mile and its westward dip is b
feet per mile.

The Fox Hills formation is exceptionall
lower Cannon Ball River, for a distance o
above its mouth. In many places it forms
from the water's edge, and the cuts made
line of the Northern Pacific afford many
It rises 80 to 90 feet above the Cannon Bal

The sandstone when unweathered is gr
es, but in weathered outcrops it is yellov
The rock is rather fine-grained and for t
and friable that it can be crumbled in the
is very common and the rock contains gr
and small ferruginous sandstone concretion
these likewise exhibiting cross-bedding.
parently due to the segregation of the
patches, cementing the sand into firm, harc
harder than the sandstone in which they ar
places the iron has impregnated certain l
durated ledges which resist weathering an
softer portions. (Plate V, Figs. 1 and 2.)
size from an inch and less to six and eight i
twisted or stem-like forms are abundant a
portions of the rock are so completely filled
cretions that they constitute the main bulk
the gray, loosely cemented sandstone form
which the hard nodules are imbedded. In t

nous sandstone rises over 150 feet above water level, the Pierre shale being exposed beneath it.

The thickness of the Fox Hills formation varies from 50 to 200 feet, and in the area under discussion is not much over 100 feet.

CRETACEOUS OR EOCENE ROCKS

LANCE FORMATION

Overlying the Fox Hills is a non-marine formation which has been variously called the "Ceratops beds," "Lower Fort Union," "Somber beds," "Laramie," "Hell Creek beds," and "Lance formation." The United States Geological Survey has recently adopted the name "Lance formation," derived from the term "Lance Creek beds," which was applied to the deposits by J. B. Hatcher, and this name is employed in the following pages. As already stated, the age of the Lance formation is still unsettled, some geologists regarding it as part of the Fort Union and thus early Eocene in age, while others believe that it includes, or is part of the Laramie, and is therefore Cretaceous.

The Lance beds have a wide distribution in North Dakota and eastern Montana, as well as in northwestern South Dakota and northeastern Wyoming. The largest area in North Dakota is that in the district under discussion, where the Lance formation occupies a large part of Morton County and all the Standing Rock Indian Reservation outside the Pierre and Fox Hills outcrops; east of the Missouri River it covers southern Burleigh and the greater part of Emmons County together with the adjoining portions of Kidder, Logan, and McIntosh counties.

As shown on the map, the Lance beds occur along the Missouri valley to within ten or twelve miles of Washburn. Wherever the streams have eroded the overlying Fort Union beds the Lance formation appears at the surface, and therefore along the valleys its outcrop extends much farther west than in the upland areas. It will be noted that the beds are exposed on the North Fork of the Cannon Ball almost as far as the Hettinger County line; on the Heart River they extend up to within eight or nine miles of the Stark County line; and on the tributary of Sweet Briar Creek followed by the Northern Pacific Railroad they outcrop as far west as Judson, near which station they disappear below the valley bottom. East of the Missouri River the Lance beds are for the most part covered with a mantle of glacial drift, and outcrops are not numerous even along the few streams of the region. For this reason the exact position of the eastern margin cannot be definitely determined, and it may lie some miles on one side or the other of its location on the map.

Fig. 1. Contact of Fox Hills sandstone and Lance fc
River. The ledge on which the man stands forms th

Fig. 2. Bluff on the west side of Missouri River nea
beds rising to a height of 350 feet abov

[redacted]

Unexposed to top of bluff ....
Clay shale, gray ....
Shale, brown, carbonaceous, with thin coal seams at and bottom; bottom coal seam two inches t and top seam one inch thick ....
Shale, brown and gray, with some sandy layers ......
Coal, with brown carbonaceous clay below ....
Shale, brown, carbonaceous, with sandstone and sa shale toward top ....
Sandstone, yellow and gray, soft ....
Sandstone, soft and loosely cemented, very ferrugi and brown, with impure limonitic concret arranged mostly in two bands, two to 1 inches thick ....
Shale, dark colored, almost black when moist, brow places ....
Sandstone, massive, shows cross-lamination, rat coarse, gray; forms vertical cliffs ....
Shale, sandy in some layers, and sandstone, soft gr contains dark brown ferruginous concretions several horizons, one near the top, but th concretionary layers are not persistent ....
Sandstone and shale, gray, in alternating layers ......
Sandstone, soft, gray, with several thin, brown, carbo ceous bands ....
Sandstone, gray and sandy shale, in alternating laye
Unexposed to river ....

Total ....

The base of the above section, the lower 15(is not exposed, cannot lie far above the Fox I since the latter outcrops only about four miles to

East of the Missouri River the Lance formati many points in Emmons County. It is perhaps the bluffs of the river in the extreme northwes county, in T. 136 N., R. 78 W. The sandstones well exposed in the cuts along the Linton Branc ern Pacific Railroad between Moffit and Lin seen several miles south of the former station, vicinity of Hazelton and Larvik. The beds ou along Beaver Creek above Linton, and in the region.

The Lance formation of south-central Nor shown by the sections along the Cannon Ball an consists of three members; an upper sandstone thick, a middle member composed of dark sha sandstone layers and having a thickness of 200 t a lower member made up of sandstones and shale layers. The latter member has a thickness of 3 and the maximum thickness of the entire Lan probably not far from 700 feet in this region.

Very little coal is found in this formation in

Fig. 1. One of the Twin Buttes, 8 miles south of Bismarck, of Missouri River. The butte is formed of Lance beds an the effect of rain erosion on the soft clays and s

Fig. 2. Outwash material at the base of one of the Twin Butte Bismarck, showing the result of rain erosio

TERTIARY SYSTEM.

EOCENE SERIES

FORT UNION FORMATION

The Fort Union is one of the most important and best known formations of the Northwest. It covers a vast area east of the Rocky Mountains, stretching from Wyoming to the Arctic Ocean in the valley of the Mackenzie River, and including several Canadian provinces, much of western North Dakota, eastern Montana, northwestern South Dakota and central and eastern Wyoming.

The name Fort Union was first used by Dr. F. V. Hayden in 1861 to designate the group of strata containing lignite beds in the country around Fort Union, at the mouth of the Yellowstone River, and extending north into Canada and south to old Fort Clark, on the Missouri River above Bismarck. It is a fresh water formation and is composed of clay shales alternating with soft, rather fine-grained sandstone, and containing many beds of lignite. The Fort Union is remarkably uniform in color, composition and appearance throughout the entire region. The prevailing color is either a light ash gray or yellow, but in places the beds are nearly white.

The distribution of the Fort Union formation is shown on the geological map accompanying this report. It will be seen that the beds have been extensively eroded, the streams having cut their valleys through the Fort Union and into the Lance beds. The former is therefore found on the upland areas where it has escaped the erosion which has swept away the beds over so large a part of the area. West of the Missouri River the boundary between the Lance and the Fort Union formations may be traced without much difficulty on account of the large number of outcrops, not only along the streams, but back from these on the uplands. East of the Missouri the drift covers these formations so that there are few outcrops and the position of the boundary can be determined only approximately.

In following up the South Fork of Cannon Ball River, also known as Cedar Creek, the Fort Union beds are first encountered nine or ten miles northwest of Lemmon, or not far from the east line of T. 130 N., R. 93 W. There are several excellent exposures here which show the typical yellow and ash gray shales and sandstones of this formation. Along Timber Creek, in T. 131 N., R. 91 W., there are numerous good outcrops, many of the beds being white, with some yellow shales. The Lance beds occur only in the southeast corner of the township. In Hettinger County the Fort Union beds are well exposed along the North Fork of the Canonn Ball River and on Thirty Mile Creek, and along the former stream they are found several miles east of the Morton County line. The white and light gray shales and sandstones out-

crop at many points north of the Cannon Ball v to twenty miles east of this line, and the format extend still farther in the same direction, as sho

On the Heart River the Fort Union is well e east line of T. 136 N., R. 90 W., where the fo occurs:

Coal, containing two-inch clay parting; the upper b which is mined at several points	
Unexposed	
Shale, yellow, forming the top of bluff bordering river; typical Fort Union	
Shale, gray and yellow, with shell layer at top	
Shale, yellow, with layer containing many shells	
Shale, ash gray	
Coal; the lower bed	
Shale, chocolate brown to black	
Shale, gray	
Sandstone ledge	
Shale, yellow and light gray, with large calcareous cc cretions near base	
Sandstone, massive, gray, exposed above river	
Total	

The lower sandstone of the above section pr to the Lance formation, while the bulk of the ov to be included in the Fort Union. The latter ap west of Judson along the creek followed by the N Railroad.

The most easterly area of Fort Union strat Heart River forms the high and narrow divide bet waters of the Little Heart River and the Heart. this divide have escaped erosion, and some 150 feet shales and sandstones are here present.

In the northeastern corner of Morton Count divide between the Missouri River and the south b Creek, in the southwest corner of T. 140 N., R. 81 clay shales of the Fort Union are found. They following shells:[1]

Corbula mactriformis M. and H.
Campeloma multilineata M. and H.
Viviparus trochiformis M. and H.

East of the Missouri River there are few exp beds. The formation is known to be present ove portion of Burleigh County, and it is found with miles of Bismarck. It does not occur much belo of 2,000 feet above sea level, or some 350 feet a All strata lying above this horizon in central B belong to the Fort Union. They are well exp

1. Identified by Dr. T. W. Stanton.

northwest of Sather, in the SW. quarter of Sec. 1, T. 140 N., R. 81 W., where the following section appears:

	Feet	Inches
Unexposed to top of hill	28	
Sandstone, very soft, and containing many shells, including gastropods and a few Unios	1	
Sandstone, soft, ash gray, fine-grained	15	
Shale, yellow, containing some limonite		4-6
Shale, ash gray	16	
Coal	1	6
Sandstone, soft, very fine-grained, gray and yellow	2	
Shale, yellow	2	6
Sandstone, fine-grained, soft, ash gray and yellow, exposed	13	
Total	79	6

The ash gray and yellow shales and soft sandstone of this section are very typical of the Fort Union formation. The following shells were collected from the upper sandstone of this outcrop:[1]

Unio sp. Fragments.
Campeloma multilineata M. and H.
Campeloma producta White.
Viviparus retusus M. and H.

At the top of the high, flat topped butte in the SE. quarter of Sec. 30, T. 141 N., R. 80 W., a yellow and gray sandstone is exposed. It is at least 50 feet thick and some layers are soft while others are hard. It contained the following leaves[2] and shells:

Populus daphnogenoides Ward
Populus amblyrhyncha Ward
Populus cuneata Newb.
Aralia notata Lesq.
Platanus Haydenii Newb. Young leaf.
Viburnum sp.
Corbula mactriformis M. and H.
Viviparus multilineata M. and H.

Most of the hills in the vicinity of Sather, and to the north and northwest of the Post Office, which have an elevation of 2,000 feet or over, are capped with ledges of an indurated sandstone which generally outcrop about the summit. Fragments which have broken from the ledges above are scattered down the slopes. This sandstone has protected the hills from erosion and to a large extent determined their present height. Since there are many sandstones in the Fort Union at various horizons and separated by no very great thickness of shale, it is difficult to determine whether these ledges capping the hills belong to one or more horizons. It is perhaps more probable that they should be referred to several horizons which are not widely separated.

1. Identified by Dr. T. W. Stanton.
2. Identified by Dr. F. H. Knowlton.

of the burning coal beds. This has been sufficient to burn the overlying clays to a red or salmon pink color and in many places to completely fuse them to slag-like masses. The beds of clinker vary in thickness from five or six to forty feet, or over, and some of them can be traced many miles in the bluffs bordering the valleys, and in the ridges and divides, while large numbers of the lower buttes are capped with these protecting layers. Such a bed of burned clay appears near the top of the bluffs bordering the valley of Big Muddy Creek for many miles above and below Glen Ullin. In the vicinity of the latter town there are three clinker horizons, the lowest about 80 feet above the railroad.

The maximum thickness of the Fort Union is not far from 1,000 feet in western North Dakota, but in the south-central part of the state the upper portion of the formation is absent. The beds have been greatly eroded, have been entirely removed over large areas, and from much of the region several hundred feet have been carried away. The thickness in Morton County is probably nowhere over 700 feet.

The Fort Union beds, which are early Eocene in age, contain a flora of nearly 400 species, and a fauna comprising both vertebrates and invertebrates.

Lists of those found in this area have been given on previous pages, and include plants and shells. Vertebrate fossils are rare in this formation, but in the western part of the state the bones of fishes, turtles, and the aquatic reptile *Champsosaurus laramiensis* have been found in the undoubted Fort Union.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

The Pleistocene deposits are very different in origin from those thus far considered. Instead of being marine or ordinary fresh-water sediments, they have been formed through the agency of the vast continental glaciers which once covered the region. They present a marked contrast to the Cretaceous and Tertiary formations not only in origin but in appearance and mode of occurrence. The deposits were formed long after the Fort Union beds were laid down and they overlie the earlier formations without regard to altitude, forming a thin veneer over part of the area, and a thicker sheet over other portions east of the Missouri River. Only in the latter region are they of sufficent thickness to modify to any notable degree the preglacial topography. The Pleistocene deposits include (a) glacial boulders, (b) till, or boulder clay, and (c) more or less stratified silt, sand and gravel in terraces along the streams, and forming the valley trains of the Little Heart basin.

THE ALTAMONT MORAINE

The broad belt of irregular hills and ridg tutes the Altamont moraine forms one of the r features of the region. During Pleistocene time tl from the centers east and west of Hudson Baj southward overspread all of New England, the ‹ the Ohio River and east of the Missouri Rivei some territory west of the latter stream. The periods during which the continental glacier ‹ the south, separated by others when it retreated left the surface free of ice. The last or most ice invasions was that of the Wisconsin ice and t most westerly moraine formed by this is known moraine. This crosses the region under discuss west to southeast and throughout this part of its twelve to fifty miles east of the Missouri River. Pacific Railroad crosses the moraine between Di ling, and the Minneapolis, St. Paul and Sault Ste. traverses it for a distance of nearly eighteen 1 several miles east of Wishek in McIntosh Count; Lehr is located in the midst of the hills formi and the railroad from Braddock to Ashley is on miles west of the moraine.

The Altamont moraine was formed alon the ice sheet where it remained stationary for a rock debris carried by the glacier being heaj cumulating to form the drift hills, which are dotted with numerous boulders. This morain rough belt of country characterized by irregul lows, the hills rising 50 to 100 feet and over vening hollows. The depressions are often fil forming the lakes and ponds so common in mor belt varies in width from about six to twenty mi Altamont moraine the shales and sandstones o and Tertiary are covered in most places by a glacial debris left behind by the Wisconsin ice Wisconsin drift. The surface of this drift shee rolling plain which stretches eastward to the R and beyond. Like the morainic belt it contains and has few streams of any size, forming an are age.

EXTRA-MORAINIC GLACIAL TILL

During one of the earlier ice invasions the cc extended far to the west of the Altamont mora Missouri River and moving forward to with of the Hettinger County line between the Canno

rivers. The ice margin between these rivers was 100 miles west of the present moraine, and nearly 60 miles west of the Missouri. The ice of this invasion probably left a sheet of glacial till west of the latter river but the fine debris composing the drift has been almost wholly removed by erosion during post-glacial time, since very little till is now found in Morton County. East of the Missouri River, in Burleigh and Emmons counties, till appears to be present over much of the area, though outcrops are not common and it is covered in many places by outwash material from the Altamont moraine.

West of the Missouri valley the glacial till is confined chiefly to the basin of the Little Heart River, where it has been heaped up into the morainic hills of that region. These hills have already been described under the heading of "Topography," and little need be added to what has already been given. The till was here deposited mostly in the form of irregular morainic hills and ridges which are commonly near the base of the slopes of the valley sides, and in the bottom of the valleys themselves. The boulder clay forming the higher hills probably has a thickness of from forty to sixty feet and over. Good outcrops showing the drift are, however, very rare. The best one occurs in a cut bank on the north side of the valley of Little Heart River, just below the mouth of the Southeast Branch, where ten feet of boulder clay, gravel and sand are exposed. Till also appears along the road on the opposite side of the valley, just east of the bridge across the branch.

The great number of boulders west of the Missouri River indicates that the ice sheet which overspread this region carried much coarse debris and it seems not unlikely that it also contained considerable fine material which would be left behind when the ice melted. This would have formed a sheet of till of greater or less thickness covering much of the area. The almost complete absence of glacial till west of the river, except in a few localities, is probably due, as stated above, to the fact that the fine materials of the drift have been removed by erosion and only the coarse debris, represented by the numerous boulders, has been left behind. The latter commonly rest directly on the bed rock.

East of the Missouri River and between that stream and the Altamont moraine more boulder clay is present, but even here the occasional outcrops appear to indicate that it forms only a thin veneer over the underlying rocks, seldom exceeding eight or ten feet in thickness. The till appears to be thin and patchy, being entirely absent over considerable areas from which it has perhaps been removed by erosion.

In the bluffs of the Missouri River three of Bismarck ten feet of till are found, and in th end of the Northern Pacific bridge across the a thickness of fifteen to twenty feet. (Plate VII, cut several good sized boulders are seen at the b Boulder clay appears in a number of the cuts neapolis, St. Paul and Sault Ste. Marie Railroa marck, generally associated with water-laid drift. line of Sec. 15, T. 139 N., R. 80 W., the following s

Soil ....

Gravel and boulders, large and small; in places this ber consists largely of boulders ....

Till, light gray ....

About three-quarters of a mile south of here, in t eight feet of shale are exposed, overlain by four containing boulders. In sec. 22, T. 139 N., R. 80 shows:

Boulder clay ....

Shale ....

In the NW. quarter of sec. 33, T. 141 N., R. 7 Union sandstone is overlain by five feet of gravell largely of local material, but containing occasio granite and other igneous rock.

In the till of this locality and others along t ready mentioned Fort Union shells are found in drift. They were doubtless incorporated in it shale and sand of that formation and large nu have been remarkably well preserved.

Boulder clay appears at several points on Ap outcrop in sec. 36, T. 139 N., R. 79 W. shows eleve stone overlain by twelve feet of till, and about fo near the line between secs. 3 and 4, T. 138 N., R. of boulder clay are exposed near the top of a cut l

In the many cuts of the Northern Pacific Ra Moffit and Linton only a little glacial till appears, ers are seen in many places. In several of the cut till was observed overlying the Lance formation.

The glacial till of south-central North Dako much of the western part of the state, is extra and lies outside the outer (Altamont) moraine. thought to mark approximately the western bord consin drift sheet. The drift which occurs outsid moraine is thin and patchy and is represented ov area by boulders and gravel. As stated on a previ the appearance of having undergone much erosion, ried away most of the glacial debris and left b

feet in diameter, large ones measuring eight a
being seen occasionally. (Plate VIII, Fig. 2) W
are most apt to occur on the upland areas, scatt
found in all parts of the region at all elevations
of the valleys to the tops of the highest divides.
on areas 2,300 feet and over above sea level, or
Missouri River, and in valley bottoms 1,650 fe
sea level Boulders are reported to have bee
two wells at Bismarck at a depth of 125 feet
or 1,545 feet above sea level.

Just north of the point where the valley of
River enters that of the Missouri the gentle sl
the bluff to the latter stream is broken by low
are thickly dotted with good sized granite
seven miles southeast of here are several low h
of the Missouri which likewise carry large b
boulders are also found in the gravel terraces
and Heart rivers.

STRATIFIED DRIFT

Considerable stratified drift occurs in Burle
counties between the Missouri River and the A
This is formed of the materials of the glacial
been sorted and deposited through the agenc
flowing from the melting ice. The deposits thu
less distinctly banded or stratified appearance
trast to the ice-laid till which is composed of
materials—clay, sand, gravel, and boulders—
gether in a heterogeneous mass.

While the Dakota lobe of the Wisconsin ice
ing the Altamont moraine, one of the importan
drainage from the melting ice was Apple Cre
long period of time that must have been require
tion of this massive morainic belt, the silt-laden
Creek were making deposits in the valley of th
crops of stratified drift which probably repre
silt are found in several cuts along the North
road, where it follows the south side of Apple

In sec. 1, T. 138 N., R. 79 W., five feet of s
overlain by three to four feet of yellow, finely
clay containing near its base pebbles and small
ite and other rock. In another cut one mile
feet of water-laid drift appear. An outcrop in
of sec. 11, of the same township and range, sho
the Lance beds overlain by seven feet of yellow,
clay containing lime concretions. Resting on th
of gravel at the top of the cut. In a deep ra

7 of T. 138 N., R. 79 W., twenty feet of strata are exposed. The lower fifteen feet are composed of finely laminated and fine-grained sand and clay, the laminae being much crumbled, broken and folded as though the deposit had been subjected to considerable pressure This lower portion of the section appears to be formed of much disturbed Lance beds. The upper five feet is unstratified boulder clay.

A second important outlet for the drainage of the melting ice was Beaver Creek, which has its source in western Logan and McIntosh counties, not far from the moraine. There is much outwash material along the valley of this creek, the deposit in many places being sand and gravel. These appear on the south side of the valley for many miles below Linton, and are also found on the low plain stretching away to the south of Beaver Creek.

Stratified drift, including gravel deposits, occurs north of Bismarck along Burnt and Hay creeks, where it is exposed in cuts along the Minneapolis, St. Paul and Sault Ste. Marie Railroad. In many of the cuts north of Arnold these glacial gravels appear resting on the Lance beds and having a thickness of three to six feet. Much of the gravel is very coarse, with many small boulders six to eight inches in diameter. In the vicinity of the Penitentiary seven feet of gravel are exposed along the railroad, and in a ditch beside the track, in sec. 15, T. 139 N., R. 80 W., is a deposit of gravel four feet thick containing boulders. Water-laid drift is exposed in the clay pit of the State Brick Yard near the Penitentiary. Twelve feet of clay and sand are seen here, there being three beds of clay separated by two beds of fine-grained sand.

Stratified drift is not confined to the stream valleys but is found in many places along a strip of country bordering the Altamont moraine on the west. Water-laid glacial debris doubtless underlies the outwash plain which borders the moraine, although outcrops of these deposits are rare. The Linton Branch of the Northern Pacific Railroad traverses the outwash plain between McKenzie and Moffit. The nearly level surface contains a number of undrained depressions which form marshes and alkali flats. Some of the larger basins are filled with water and form lakes, of which Long Lake is an example. Napoleon is located on such an outwash plain and the lake near town occupies a shallow depression, which is swampy in places and almost dry at times. The glacial drift here contains an abundance of fine gravel.

GLACIAL TERRACE DEPOSITS

These glacial deposits are confined to the vicinity of the streams and in their formation the materials of the drift have

been sorted through the action of running w
least the streams swollen by the drainage f
ice have been instrumental in their formatio
deposits considered under this heading were
some time after the deposition of the till, but i
believed to have had their origin during the Pl

Extensive gravel deposits form a terrace
side of the Heart River valley, and they are we
30, 33, and 34, T. 139 N., R. 81 W., and in se
R. 82 W. The wagon road leading south fr
crossing the Heart River by the new bridge ne
of sec. 34 passes through a cut just south of the
gravel is here well exposed. Layers of grave
beds of coarse and fine sand. Good sized pebble
other igneous rocks are not uncommon, many ha
of five to six inches. An extensive exposure of t
in the large pit in sec. 30, T. 139 N., R. 81 W., to
track from the Northern Pacific road extends.
has an elevation of 70 feet above the Heart Ri
posed largely of very coarse gravel and boulders
inches in diameter, with finer gravel and a little
bles and boulders are of glacial origin, a large p
material being unlike the underlying rock, an
granite, gneiss, quartzite, etc., with some loca
mostly the harder sandstone of the Lance beds.
large glacial boulders are scattered over the
terrace and others are found mingled with the g

In the construction of the new branch line
Pacific Railroad north from Mandan a cut was
edge of the terrace bordering the Missouri, about
of town. In this the shales of the Lance beds ar
to 40 feet above the river, and resting on them
gravel and sand having a maximum thickness
Mingled with these materials are granite bo
three feet in diameter, some of them resting
shales of the bed rock. Considerable coarse la
mixed with the gravel, and overlying it in plac
feet of clay and fine sand, probably washed down
back from the river.

The terrace on the west side of the Miss
of the Little Heart and extending also a few mi
latter river, is formed in part of Lance beds ov
gravel and silt. These deposits are well shown
railroad cuts in the vicinity of Sugarloaf Butt
northwest corner of sec. 36, T. 137 N., R. 80

points on the edge of the terrace. The following section, which is fairly representative, appears in one of the cuts:

	Feet
Glacial silt and wash from the bluffs	2-10
Glacial gravel	1-5
Lance beds, exposed to bottom of cut	8-10

As shown in this exposure the gravel and silt vary considerably in thickness, but they appear to be generally present on this terrace, the silt always being at the top.

Reference has been made on a previous page to the terrace at Bismarck. It lies 45 feet above normal water level, and the materials composing it are exposed a little below the steamboat landing near the Northern Pacific bridge. The terrace is here seen to be formed in part of gravel and sand, overlain by several feet of finer material, either river silt or wash from the nearby bluffs, or both. Part of Bismarck is built on the terrace, Fort Lincoln is located on it, and it extends nearly two miles farther south, its width being about two miles. Glacial terraces also occur at various points along Beaver Creek and are well shown for several miles below Linton.

Fig. 1. Northern Pacific bridge over the Missouri River

Fig. 2. Boulder covered hill of the moraine in Little Heart basin

L. Darling, the writer was allowed to examine these records, and the following, selected from 44 borings, are given as representative of the materials passed through.

Records of borings in channel of Missouri River near the Northern Pacific Bridge at Bismarck.

BORING NO. 21.

	Feet
Sand, fine	47.4
Gravel, clear	2.2
(At this depth struck a hard boulder and hole was abandoned)	

BORING NO. 24.

Sand, fine	33
Sand, coarse, and gravel	11
Sand, fine black	½
Sand, coarse, and gravel	10
Clay (shale) penetrated	3.9
Total thickness of alluvium	54½

BORING NO. 34.

Sand, fine	22.5
Sand, fine, and coal	7
Sand, coarse, and gravel	4
Gravel	2.5
Clay (shale) penetrated	5
Total thickness of alluvium	36

BORING NO. 13.

Sand, fine	28
Gravel	2
Sand, fine, with a little coal	19
Coal and small balls of clay	.8
Sand, coarse, gravel and coal	10.2
Sand, fine, black	.2
Gravel, coarse, and fine sand	9.2
Clay (shale), blue, and sandstone, penetrated	15.4
Total thickness of alluvium	69.4

BORING NO. 42.

Sand, fine, with gravel and coal	36.2
Sand, coarse	11
Gravel	2.2
Clay, blue	.8
Sand, fine, dark	13
Sand, coarse	5.5
Gravel, coarse	3.2
Clay (shale), penetrated	6.5
Total thickness of alluvium	71.9

BORING NO. 44.

Sand, fine	26.1
Coal	1.2
Sand, coarse, and pebbles	16.5
Sand, fine, and coal	4.5
Sand, coarse and pebbles	3.4
Clay, blue	.6
Sand, fine, dark	11
Sand, coarse., and gravel	9

After the Fox Hills sandstone had been conditions came to an end and the sea withdrev never again to return. The next rocks to be Lance beds, which were probably accumulated lake or lakes. The fine and coarse sediment fresh waters, and resting directly upon the Fo produced the alternating shales and sandstone Lance beds. In certain localities marshes formed, due in many instances doubtless to the basins with sediment, and the vegetation whi marshy places accumulated to form coal bed great land reptiles or dinosaurs were abund sented by the massive and clumsy *Triceratops*, roamed in large numbers along the shores of lak

TERTIARY PERIOD

Deposition continued during Fort Union tin a great extension of the fresh water lakes un large portions of North Dakota, Montana, Wyom Canada. In the waters of these basins were de stones, clays, and shales of the Fort Union. Th lary favorable time for coal formation, there tensive swamps in which grew and accumulated the coal-forming trees and other plants. As ma of plants are known to have been living at this t being a Sequoia which is related to the giant r ifornia, and their remains were preserved in rocks.

At the close of Fort Union time depositio region, although 50 miles to the west it contin gocene and fluviatile and locustrine sediments mammalian remains accumulated to a thicknes feet. Throughout most of the Tertiary perio rising and was subjected to long continued an ion, resulting in the removal of hundreds of fe large areas, and the formation of the broad, de Missouri, the Heart and the Cannon Ball, an numerous tributaries. During this Tertiary souri River cut its valley to a depth of nearly 8 present upland surface and to a width varying f and a half miles. The present relief, the topogr the region, including the high ridges and divi buttes, the escarpments, and the stream valleys in large part by erosion during the Tertiary per of the greater portion of the area was thus r to the extent of from 100 to 800 feet or more.

over twelve miles by its clinker bed, and it probably had an areal extent of at least 200 square miles.

COAL IN THE LANCE BEDS

Coal is by no means as abundant in this formation as in the overlying Fort Union, and over extensive areas it contains no beds of workable thickness. In the region under discussion only two or three coal beds belonging to the Lance formation are of sufficient thickness to be mined. One of these workable seams is exposed in the valley of the Little Heart river and tributary valleys in the eastern portion of T. 137 N., R. 81 W. The coal lies about 100 feet above the Missouri river or a little over 1,750 feet above sea level, and has a maximum thickness where worked of 6 feet 7 inches, though in most places it is not over 5 feet thick.

At the Kipoven mine, in the NE. quarter of sec. 25, T. 137 N., R. 81 W., the section of the coal bed is as follows:

	Feet	Inches
Shale		
Lignite		2-3
Clay		5
Lignite	1	7
Clay		3-4
Lignite	5	
Shale		

The coal is mined by drifting in along the bed from the outcrop, the 5-foot coal bed and overlying clay parting are removed and the 19-inch coal bed is left to form the roof. Coal has been mined from this opening for about four years and the drift is in over 300 feet, the lignite being run out on cars. Farmers are reported to come to this mine for their coal distances of 15 to 20 miles from the south and southwest. The lignite sells at the mine for $1.25 a ton.

This coal bed has been mined by drifting into it in five or six other places along its outcrop in the valley in sections 24 and 25, T. 137 N., R. 81 W. In the SE. quarter, sec. 24, the section of the bed is as follows:

	Feet	Inches
Shale		4
Lignite		4
Clay		7
Lignite		7
Clay		2
Lignite		5
Clay		7
Lignite	4	5
Clay shale		

What is doubtless the same coal bed has been opened up along its outcrop at several points in the ravine in the NE. quarter, sec.

26. The coal is here thinner, ranging from tl
four feet, and the clay parting over the lower c
The lignite has also been mined in the NE. q
of the same township and range.

All the above localities are south of the L
but the same coal has been opened up in a nu
the north side of the river, particularly in t
sec. 14, T. 137 N., R. 81 W., where the bed is a
a half feet thick. It is being mined at pr
quarter, sec. 14, and the drift runs back sev
from the face of the outcrop. The coal is bro
running on wooden rails with strap iron naile
lignite bed is here 33 inches thick and one foot
is removed to give more room for working. A p
in sec. 12, shows 34 inches of coal.

Where the bed has been prospected to the
east it is found to be thinner and the coal is
seams by partings of clay. It has been uncove
along its outcrop in sec. 7, T. 137 N., R. 80 W
here measures only one foot in thickness. In
bluff at the mouth of Little Heart River, on wh
tion station was established, the following th
representing the workable coal bed found elsew

Shale	
Lignite, shaly	
Clay	
Lignite	
Shale, brown, carbonaceous	
Lignite	
Shale, brown, carbonaceous, with one-inch coal sean	
Shale and sandstone to river level	

It will be seen from the above section tha
is here split into three which are separated b
shale.

The mines are worked only in the fall an
Little timbering is used near the entrance.

The Little Heart coal bed does not extend
two miles north of the river, since it grows tl
rection and splits into several thin beds with cla
The coal bed has been extensively eroded in
Little Heart and its tributaries, the main valley
to a depth of 50 to 100 feet below the coal. S
it is known to extend into section 25 and 26, T.
and how much farther has not been ascertain
rises rapidly to the upland level, where the coa

In the following discussion the southernmo described, and then in succession those occurri

COAL IN EASTERN ADAMS COUNTY

A thick coal bed is present near the to ridges and divides north of Haynes, between H Cedar creeks. The coal lies well above the l rounding surface, and except where preserved elevations it has been removed by erosion. To the ridges and buttes of this vicinity there is burnt clay or clinker formed by the widespread same thick coal bed. This coal, which is mined i dozen different places, has a thickness of 12 to 1

The following mines are located within two and all are mining the above mentioned 12-feet c

Brown Mine, owned by the Haynes Coal & located in the SE. quarter, sec. 8, T. 129 N., R. opened in June, 1908.

Farmers Coal Association Mine, located in se 94 W., on the opposite side of a ridge from the B

Haynes Coal Company Mine, located in t sec. 16, T. 129 N., R. 94 W.

Peterson Mine, also in sec. 16, T. 129 N., R.

The last three mines have been opened sinc 1908. In all the seam is reached by a slope, u is drawn by horses. Eight or nine feet of coal a three or four feet are left to form the roof. Th feet of good clean coal with no clay partings. the mine for $1.75 a ton. The lignite is almost woody than much of the North Dakota coal.

Two other mines in the vicinity of Haynes same thick coal bed, namely, the Pinkham n T. 130 N., R. 94 W., and the Holdridge Mine, N., R. 94 W.

This Haynes coal bed, as it may well be na not far from 150 to 200 feet above the base of th

At the northeast corner of Adams County mined on Sheep Creek, near the east line of T. The lignite is obtained by stripping, but the b exposed and its thickness could not be determin

COAL IN SOUTHEASTERN HETTINGER COUNTY

A coal bed $7\frac{1}{2}$ feet thick is worked by stripping at the Kuntz mine, in the SE. quarter, sec. 33, T. 132 N., R. 91 W. Though the lignite has a thickness of $7\frac{1}{2}$ feet in the thickest part, it grows thinner toward the east and west. From three to five feet of cover are stripped off to reach the coal, which is clean and free from clay partings. Farmers come to this mine for many miles around, some traveling as far as ten or twelve miles, for their winter supply of fuel.

Fourteen miles northwest of the Kuntz Mine a lignite bed is mined not far from the headwaters of Timber Creek, near the NW. corner of T. 132 N., R. 93 W. The full thickness is not exposed, but there is at least 5 feet of coal. A 6-foot bed of coal outcrops on the Cannon Ball River five miles east of the Hettinger County line, and it is not unlikely that this seam continues west into the latter county. Some ten or twelve miles west of the line a coal bed appears on the Cannon Ball in townships 133 and 134 of range 92. It has a thickness of 3 feet and is good lignite.

COAL IN MORTON COUNTY

In the southwestern part of the county a coal bed is present near the base of Coffin Buttes. It is 9 feet thick, contains four thin clay partings, and is mined at several points by stripping. The Corral mines are located in sec. 32, T. 132 N., R. 90 W., one on the north side and one on the south side of the section. Many farmers living to the south drive to these mines a distance of 12 to 15 miles. The same bed is mined in three places in sec. 35, T. 132 N., R. 90 W.

A coal seam near Fleak has been mined by stripping at several points. One mile north of the Post Office 4 feet of coal appear where the seam has been exposed by the removal of the overlying clay. It is probably the same bed which is worked one mile east of Fleak and also several miles to the north. This coal bed is perhaps to be correlated with the upper of the three beds of lignite which appear in the bluffs of the Cannon Ball River six miles south of Fleak.

The Fort Union formation is well exposed in the bluffs of the Cannon Ball for many miles above the boundary of the Lance beds. The position and thickness of its lignite seams are shown in the following section, exposed in the high bluff on the north side of the river, in sec. 5, T. 133 N., R. 89 W.:

	Feet	Inches
Shale	44	
Coal	4	2

miles to the southwest. This coal is mined in sec. 36, T. 135 N., R. 89 W., and has been worked at many points for a distance of nearly one mile, on the south side of the valley of Antelope Creek. A section of the coal bed is as follows:

	Feet	Inches
Sandstone	10-16	
Coal		10-12
Clay shale	1-5	
Coal, bottom not exposed, but at least	3	

It will be noted that the clay seam varies greatly in thickness, being only a foot in places and elsewhere thickening to 5 feet. In order to reach the coal the thick overlying soft sandstone is removed by stripping, and at some points it has been necessary to scrape off as much as 10 to 15 feet of rock before reaching the lignite.

A higher coal bed which is perhaps the upper coal bed of the Cannon Ball section is mined several miles southwest of Leipzig, in secs. 25 and 26, T. 135 N., R. 90 W. The coal is 30 to 32 inches thick and mining by stripping has been carried on here for eight or nine years.

Two coal beds are present along the Heart River valley near the western edge of Morton County. They appear in the following section which is exposed on the Heart near the east line of T. 136 N., R. 90 W., six miles from the Hettinger County line:

	Feet	Inches
Shale and sandstone		
Coal, 150 feet above river, mined at many points, contains 2-inch clay parting	4	
Unexposed	41	
Shale, yellow, forming topmost layer of the river bluff	19	
Shale, dark gray and yellow, containing two shell-bearing beds	33	
Shale, ash gray	2	4
Coal		24-30
Shale, brown to black at top	2	
Shale, gray	2	6
Sandstone ledge	1	6
Shale, yellow and ash gray, containing large calcareous concretions near base	21	
Sandstone, massive, gray, the upper sandstone of the Lance beds, exposed above river	26	

As shown in the above section the lower coal bed lies near the base of the Fort Union, which is at or near the top of the lower sandstone. The upper coal lies 95 feet above the lower. This 4-foot bed is mined by stripping in secs. 3 and 4, T. 136 N., R. 89 W. The lower 24-inch bed was traced several miles in the river bluffs, where it had burned out in places and formed a bed of clinker.

the first of the four, if they are actually present, must be in the Lance beds, which as we have seen are not far below the surface at Sims. But, as has been previously stated, the Lance beds of south-central North Dakota are barren of coal throughout most of this region, and the accuracy of the above log may be questioned, particularly since it was given from memory. Thin coal beds associated with black, carbonaceous clay, may have been mistaken in the drilling for the thicker seams of coal reported by the driller. But while there is some doubt about these lower seams of workable thickness being present in the Lance beds, there is abundant evidence that a number of coal beds occur above what we may call the Sims coal bed, meaning by this the one so extensively mined at that place. These higher lignite seams are found in the vicinity of New Salem, Glen Ullin and Hebron.

Coal Near New Salem—At least two workable coal beds occur in the vicinity of New Salem. Both were struck in a wall between two and three miles southwest of town, where the section is as follows:

	Feet
Shale and sandstone, having here a thickness of	45
Coal	6
Shale	35
Coal	6
Shale	

The upper coal seam outcrops along many ravines and valleys south of New Salem, where it has been mined at a number of points. It lies about 160 feet above the Sims coal bed, and 50 to 80 feet below the elevation of the upland in this vicinity. The old mine of the Consolidated Coal Company, located one mile southwest of New Salem was in this upper 6-foot coal bed, and was for several years the largest mine in Morton County, though it is no longer operated. What is doubtless the same seam has been mined in secs. 4 and 5, T. 138 N., R. 85 W., and also in secs. 34 and 35, T. 139 N., R. 85 W.

During the past year (1911) a new mine has been opened near New Salem by the Dakota Coal Products Company. It is located northeast of town, in the SW. quarter of sec. 15, T. 139 N., R. 85 W. The coal bed mined by this company runs about 5 feet in thickness and is the lower of the two seams occurring in the vicinity of New Salem, lying 30 feet below the bed mined by the Consolidated Coal Company southwest of town. The coal is 40 feet below the surface and 65 feet below the Northern Pacific Railroad. Its elevation above sea level is not far from 2,100 feet. A spur track connects the mine with the main line of the Northern Pacific, half a mile distant. A shaft has been sunk to the coal and the mine is operated by electricity.

Coal is also present in the northeastern corner of Morton County, in the western part of T. 140 N., R. 82 W., near the headwaters of one of the branches of Otter Creek. It is shown by outcrops that occur in sections 17, 20, 29, and 31. The coal bed is 4 feet thick and lies so near the surface that it is mined mostly by stripping off the cover.

From the data given above regarding the coal beds of northern Morton County it will be seen that there are at least six of these beds in the Fort Union of this region, namely, two at Sims, two at New Salem, three about Glen Ullin but two of which are thought to be the same as those at New Salem, and at least one in the vicinity of Hebron. A section showing the coal beds of this area is as follows.

		Thickness	Approximate elevation above sea level
6	Hebron coal bed	7	2,450
5	Coal bed, represented by burnt clay near Glen Ullin	unknown	2.300
4	Coal bed, the upper bed at New Salem	6	2,130
3	Coal bed, the lower bed at New Salem	5-6	2,100
2	Coal bed, exposed near Sims	4	1,987
1	Sims coal bed, the one mined so extensively	7⅔	1,970

Only one of the three coal seams occurring in the vicinity of Glen Ullin is noted in the above section, since it seems probable that the two lower beds are the same as those found near New Salem, though they are 50 feet or more higher than the latter.

Coal in Oliver County—Lignite occurs at many points in this county and it is quite likely that the New Salem seams extend north into this area. In T. 141 N., R. 86 W., a 6-foot coal bed is reported in secs. 33 and 36, and a 5-foot bed in secs. 3 and 11. Coal is said to be abundant in sec. 28, T. 141 N., R. 83 W. A bed 6 feet thick is reported in sec. 9, T. 142 N., R. 86 W., and a 7-foot bed in sec. 9, T. 142 N., R. 85 W. In the eastern part of the county, near the Missouri River, lignite is mined for local use in the northern part of sec. 7, T. 142 N., R. 81 W. In the easternmost of the small strip pits the bed measures 3 feet 6 inches, but is said to contain much dirty lignite. There are probably two beds here, the upper being mined farther west, up the draw. These beds are about 80 feet above river level.[1]

Coal in Burleigh County—Practically all the mines in this area are in the northwestern part of the county, in the vicinity of Wilton. The Washburn Mine, in sec. 1, T. 142 N., R. 80 W., is the largest and most thoroughly equipped mine in North Dakota.

1. Bull. U. S. Geological Survey, No. 381, p. 22.

The coal bed is reached by a shaft 60 feet d varies in thickness from 8 to 13 feet and has a near the bottom. The entries are unusually wi is necessary. As a rule, 6 to 8 feet of the coal ar leaving lignite for a roof, which is taken down are pulled. The underground equipment, which and efficient, consists of electric undercutting electric motors for haulage.

A little over one mile east of the above n quarter, sec. 6, T. 142 N., R. 79 E., at the Lind M is 11 feet 10 inches thick, and lies 35 feet below t

The Eckland Mine is a small opening in sec. 79 W. The lignite is about 8 feet thick, with 4 One mile east, in sec. 9 of the same township a Peterson mine. While it is doubtless on the sa the coal here is 11 feet thick and under a cover

The Yiengst Mine, located in sec. 34, T. 142 in a 6-foot coal bed, under 60 feet of cover. Nea River, in sec. 3, T. 142 N., R. 81 W., a bed of lig exposed, but its entire thickness could not be dete two miles to the north a bed which is probably section 3 shows a thickness of 7 feet.[1]

Chemical analyses and producer gas, briquetti tests.—The following analyses and producer gas t of samples taken from the Washburn Mine at W the general nature and composition of the fuel.

Analyses of Lignite from Wilton, North Da

		Mine 8
Air-drying loss		32.30
Proximate	Moisture	40.53
	Volatile matter	27.05
	Fixed carbon	27.37
Ultimate:	Ash	5.05
	Sulphur	.76
	Hydrogen	——
	Carbon	——
	Nitrogen	——
	Oxygen	——
Caloric value determined:		
	Calories	3.691
	British thermal units	6,644

These analyses were made at the fuel-testi United States Geological Survey at St. Louis.

Another consideration that adds materially the lignite is its surprising success in the produce

1. This information regarding coal in Burleigh County Geol. Surv. No. 381, pp. 22 and 23.
2. Bull, U. S. Geol. Survey, No. 290, 1905, p. 138.

vertical pug-mill. The brick are dried in open yards and burned in scove kilns with wood fuel. They are red and porous, but quite strong.

GRAVEL AND SAND

Gravel and sand suitable for building and other purposes occur along many of the streams of the region, where they form the terraces already described. The most extensive deposits of these materials are probably those along the Heart River valley. They appear across from Mandan, on the south side of the Heart, where gravel and sand pits have been opened in the terrace at many points in sections 33 and 34. Two and one half miles west of Mandan, in the south half of section 30, a spur track runs into a large gravel pit where the railroad secures rock for ballast. The material is here mostly a very coarse gravel, containing many small and some good sized boulders. That there is a large supply of gravel here is shown from the fact that this terrace deposit extends along the valley for nearly two miles, with a width of over a quarter of a mile and a thickness of 40 to 50 feet. Near Bismarck an abundance of material for building purposes, for surfacing roads and streets, and for other uses, is found in the terrace of sand and gravel which extends west of town to the Missouri River and south to Fort Lincoln and beyond. The spur track running to the steamboat landing follows near the edge of this terrace. Other deposits of gravel and sand occur along the Cannon Ball River and Apple, Burnt, Hay, and Big Beaver creeks, as well as in many other localities. Extensive gravel beds are found along the south side of the latter creek just below Linton, in the northern part of T. 132 N., R. 77 W. West of the Altamont moraine, particularly in the vicinity of Napoleon and south to Wishek and beyond, there is much gravel and sand which represent outwash materials from the moraine.

WATER RESOURCES

SURFACE WATERS

The surface waters include streams, lakes, and springs. The area is well supplied with streams and these furnish water for stock throughout most of the year. These surface waters are for the most part unfit for drinking purposes, but the Missouri River supplies the cities of Bismarck and Mandan with excellent water, and Fort Lincoln obtains its supply from the same source.

The determination of the surface water supply of any area depends (1) on a knowledge of what is the total annual run-off per square mile for the region, and (2) on a knowledge of how the run-off is distributed through the year. For an excellent discussion of the surface water supply of North Dakota the reader is referred to a paper by Professor E. F. Chandler in the Third

be mentioned the following: steepness of slopes, amount and character of vegetation, the character and depth of the soil, and the geologic structure. In the same locality in different years the run-off varies with the climatic influences, such as the amount of rainfall, whether the latter is in form of torrential rains or gentle showers, the temperature of the air and earth, and the wind velocity.

The amount of water carried by many of the streams of the state has been determined and their stream flow is known. This is expressed in "second-feet," by which is meant the number of cubic feet of water flowing past a given point in one second. From this the total quantity discharged in a year can be found; and then by division by the total number of square miles drained by the river above the point of measurement the average quantity of water that flowed during the year from each square mile of the drainage area is found. Definite knowledge of the mean flow of any stream is necessary that the quantity of water available for any purpose, such as irrigation or water power, may be determined.

In comparing the rainfall and run-off it is more convenient to express the latter as the total depth in inches from the drainage area in a year.

Of the total rainfall of the region, how much finds its way into the streams and constitutes the run-off?

The mean annual rainfall for south-central North Dakota is between fifteen and seventeen inches. During the seventeen years from 1892 to 1908 the average rainfall at Bismarck was 16.10 inches, the minimum being 13.67 (1898) and the maximum being 18.22 inches (1906). Nearly the whole of this is evaporated since the average annual run-off is less than an inch, as shown by the following table:

Total Run-off of Heart and Cannon Ball Rivers, Showing the Depth in Inches on Drainage Area.

	1903	1904	1905	1906	1907	1908	1909	1910
Heart River at Richardton	0.6	1.2	0.3	1.5	0.8	0.5	1.4	1.1
Cannon Ball River at Stevenson	0.6	0.6	0.6	1.1	0.6	0.9		

The mean annual run-off for the years 1903 to 1908 inclusive expressed in inches, was seven-tenths of an inch for the Knife and Cannon Ball rivers and eight-tenths of an inch for the Heart River.

The normal distribution of the total annual flow among the months of the year is illustrated by the Cannon Ball River, which may be taken as typical of the other streams of the region.

Mean Monthly Run-off of Cannon Ball River, Ex

Cannon Ball River at Stevenson—

Jan.	Feb.	Mch.	April	May.	June	July	Aug.	Sept.
.00	.01	.10	.11	.12	.26	.04	.02	.01

Comparing this latter table with the one s run-off during a series of years it will be noted al flow varies relatively much more than the t

Variations of stream flow are to be expecte fall is much greater in some years than in othe erable amount of the excess rainfall must re in fact a much greater part of the excess tha rainfall.

Further discussion of the streams of sou Dakota will be found in the chapter on draina pages of this report.

Springs are of rare occurrence in this region of water they furnish is too small to be of impor of supply. In many places the water seeps out afford a supply for stock and domestic use, made of such seepage and it serves chiefly to fu source of water to the streams, and enables the continuous flow throughout the year. If it w ground water thus reaches the streams by seep continue to flow only during and shortly after channels would be dry much of the time between

The lakes of the area are found only east River, where they occupy depressions in the gla ing the outwash material from the Altamont m equal deposition and accumulation of the drif pressions in its surface and these gave rise to the lakes, and marshes of the region. Some attain as for example Long Lake and the large lake ne the great majority are small, while many have or become marshes. During much of the year th water for stock, but in many instances it is not mestic use.

SHALLOW DUG WELLS

Shallow dug wells furnish sufficient water mestic purposes throughout much of the region. plied with water from the surface which has soak the soil and subsoil and has in most instances before reaching the wells. West of the Missouri of these wells is found either in the shales a the Lance and Fort Union formations, or in the

valleys. When in the clay shale the water generally seeps slowly into the wells and if much is drawn off at one time it may require several hours for the water to reach its former level. If the water is in sandstone or silt it moves more freely and enters the well almost as fast as it is pumped out. Most of the wells sunk in the flood plain of the Missouri or its larger tributaries go down only 15 or 20 feet before reaching a good supply of water.

East of the Missouri River the water of many of the shallow wells occurs in the glacial drift and the gravel and sand layers of this deposit commonly yield an abundant supply.

The waters of the surface wells vary greatly in composition, but they are for the most part suitable for domestic purposes except that some are quite hard and others contain more or less alkali.

TUBULAR WELLS

Bored or tubular wells with a depth of 75 to 250 feet are common in the region under discussion and form one of the principal sources of water supply. The wells of the Electric Light Plant and Creamery at Bismarck are 130 feet deep and the water occurs in a bed of coarse sharp sand containing fragments of lignite. Resting on the sand is a bed of granite boulders which were encountered in sinking the wells. At the Penitentiary this boulder bed was struck at 200 feet. The two wells bored some years ago at Fort Lincoln and which for a time furnished the water supply of the post, had a depth of 98 feet and were 10 inches in diameter. They doubtless went down into the sand layer at the base of the river silt, the same sand bed as that encountered at Bismarck.

In western Burleigh County most of the bored wells have a depth varying from 150 to 240 feet, the water occurring in a soft sandstone. The supply is abundant and the water is very soft. The well at Sather is 150 feet deep and another two miles north, in sec. 5, T. 140 N., R. 80 W., which is on the upland, has a depth of 210 feet. A well in sec. 10, T. 140 N., R. 79 W., reaches water at 112 feet, and one two miles to the south is 240 feet deep. In sec. 10, T. 138 N., R. 79 W., water is found at 90 feet, and many of the wells in southwestern Burleigh County outside the Missouri bottoms have a depth of 200 feet and over.

The water of most of the tubular wells of the area under discussion is found in the soft sandstones of the Lance formation and occurs at several horizons within 250 to 300 feet of the surface. In northern and western Morton County, and in some townships in northwestern Burleigh County water is struck in the sandstone beds of the Fort Union, while in much of eastern Burleigh and the greater part of Kidder County the supply comes

either from these same Fort Union sandston from the sand or gravel layers of the glacial formation.

DEEP WELLS

Deep borings have been made at Bisma Sims in an attempt to reach artesian flows, b unsatisfactory. None of these wells penetrat reach the Dakota sandstone, which is the sou artesian water of eastern North Dakota. In t the state this sandstone lies over 2,000 feet as is shown by the fact that the Mandan wel though it attained this depth.

The Bismarck well found no flows, thoug have reached a depth of 1315 feet, passing t occasional thin limestone beds. It fell far sho water-bearing beds of the Dakota sandstone. Mandan went down 2,000 feet but was apparen enough to reach the Dakota sandstone. The on is a small flow from a depth of 357 feet, estim lons per minute, but it is soft and clear. Belo loose sandstone which supplies this flow anoth a small flow was reported from 410 to 470 feet. stone with a thickness of 60 feet probably belon formation. From 470 to 1,500 feet the material and blue shale, while from 1,500 to 2,000 fee mostly in shale, as near as could be learned.[1] stone at Mandan, therefore, lies more than 2,0 bottom of the Missouri River valley, or over 3 level.

In the deep boring at Sims, which reache feet, no water was found. The record of this b by Darton, in the report just referred to, as gi by the driller. The log is as follows:

9. "Drift" ....
8. Sandstone and shale, with three coal beds, t 8 feet and the lower two 5 feet thick. The u is at the top and lower is at base of this numb
7. Sandstone, soft ....
6. Coal ....
5. Sandstone, soft, with hard bed at base ....
4. Shale, with sulphur ....
3. Sandstone, soft ....
2. "Coal," good ....
1. Shale, with sulphur ....

Total ....

---

1. N. H. Darton, "Preliminary Report on Artesian Wa Dakotas," 17th Annual Report, U. S. Geol. Survey, part 2,

Number 8 of the above section probably belongs to the Fort Union, while numbers 4 to 7 are doubtless to be referred to the Lance formation. Numbers 2 and 3 are perhaps likewise to be included with the latter, in which case the Fox Hills sandstone is absent in this locality and the thickness of the Lance beds is 580 feet. The lower 600 feet of the section (No. 1) is Pierre shale. It will be noted that two workable coal beds (Nos. 2 and 6) are reported as occurring in the Lance formation. As stated on a previous page, the presence of thick coal seams in this formation is rare and it may be that the thickness of the coal was overestimated, since a correct estimate is difficult when the ordinary churn drill is used.

SOILS

Soils are produced by the decay or breaking down of pre-existing rocks through the action of the various weathering agencies, and the mineral constituents are mingled with the carbonaceous matter derived from the many generations of plants which have lived and died on the surface, thus contributing their organic material to the superficial layer.

Considered with reference to their origin the soils of this region may be grouped in two main classes: (1) those which are residual and (2) those which have been transported.

RESIDUAL SOILS

These soils cover by far the greater portion of south-central North Dakota west of the Missouri River. They are formed by the weathering and decomposition in place of the shales, clays, and sandstones of the Lance and Fort Union formations. These rocks break down quite readily to form a sandy clay or loam which is mixed with vegetation and produces an excellent soil. Although a portion of this area west of the Missouri River was covered by the continental glacier and undoubtedly received a deposit of drift, the finer portions of this glacial debris have been almost wholly removed from most of the region, leaving behind the gravel and boulders of the drift, resting directly on the bed rock. The soils of this glaciated portion of the area are thus largely residual and formed chiefly by the weathering of the bed rock in situ, although there is in places an admixture of foreign material brought by the glacier.

In localities where the bed rock is chiefly sandstone the soils are composed largely of sand, while in other localities underlain by shale the soil contains a large proportion of clay. But for the most part it is a mixture of sand and clay in varying proportions, forming a loam.

TRANSPORTED SOILS

These soils are composed of materials brought from a greater

[redacted]

or less distance through the transporting ag
and the wind.

Glacial Drift Soils.—The soils of the drift
sand, gravel, and boulders which were gath
during its advance and deposited beneath ar
the ice. The materials have been derived in
ites, gneisses, and limestones far to the
part from the clays, shales, and sandstones
mingled together to form a soil containing a
uents. During the formation of the massive
the waters flowing from the melting ice spr
composed of the finer materials of the glacial
of considerable width west of the moraine.

The glacial drift soils are confined mostl
the area lying east of the Missouri River, sin
they are thin and patchy, and merge into t
the region.

Alluvial Soils.—Rich alluvial soils occur
toms of all the larger streams, including n
valley of the Missouri but those of the Cann
Little Heart rivers, and Beaver, Apple, Big
Butte creeks, with their larger tributaries.
consist in part of the flood plain deposits for
in recent times, and in part of the glacial gr
deposited by the streams during the Glacial
terraces which have an elevation of 15 to 30 f
ent flood plains. In places these alluvial so
appearing as broad sandy flats along the Miss
the most part they are composed of fine silt,
plain is being added to from time to time by
river. The soils of the stream terraces gener
of gravel and sand.

Dune sand soil.—Reference has already bee
area southeast of Bismarck, where the sand co
miles. The soil of this and other small tract
almost wholly of quartz sand, which has accu
siderable depth through the action of the wi

THE PHYSIOGRAPHY OF TH

DEVILS-STUMP LAKE RE

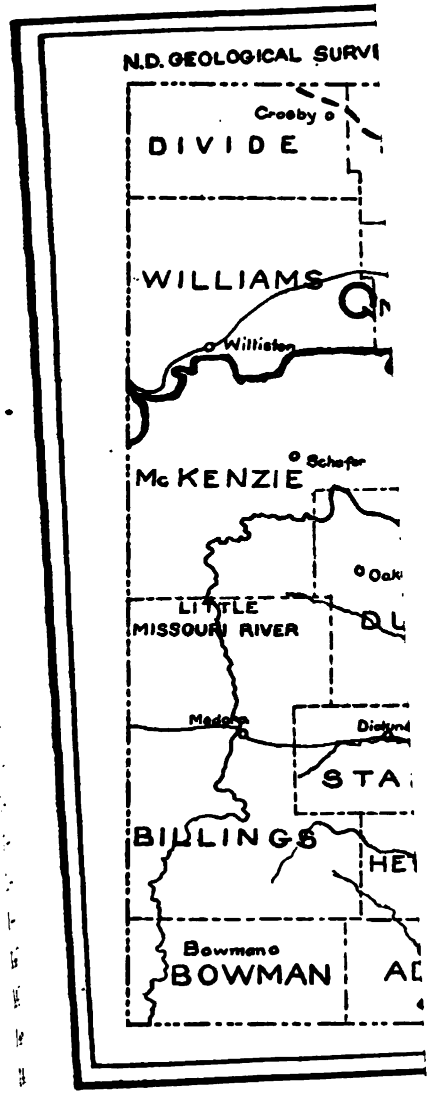
NORTH DAKOTA

BY

HOWARD E. SIMPSON

THE PHYSIOGRAPHY OF DEVILS-STUMP LAKE REGION, NORT

Contents.



N.D. GEOLOGICAL SURV
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DIVIDE
WILLIAMS
Williston
Schafer
Mc KENZIE
LITTLE
MISSOURI RIVER
Medora
BILLINGS
Bowman
BOWMAN

THE PHYSIOGRAPHY OI
THE DEVILS-STUMP LAKE REGION, NC

By Howard E. Simpson.

INTRODUCTION.

The purpose of this report is to describe ı cal features of the immediate vicinity of Devils in North Dakota, explaining their origin and ge and at the same time using these features as aı standing of the general principles of physiog under consideration is located near the cenı eastern quarter of North Dakota, as indicate panying physiographic map of the state, Plat tion of the more important places mentionec shown on the detailed map of the region, Plaı pected that this preliminary paper will be fol complete and detailed report as soon as the suı is completed.

In the preparation of this report the fe have been freely drawn upon, especially the graph of Upham,[1] the more popular work of ' report of the Fish Commission,[3] the several reı Dakota Geological Survey[4] and a recent maı the State Engineer.

Acknowledgment is due to the following assistance rendered in connection with course session of the University of North Dakota: Mr gate, Mr. T. T. Quirke, and Miss Inga Knudsoı A. Brannon and the staff of the State Biolo hearty cooperation in the study of this region the author is also indebted for the draught sketches accompanying this report.

This region is of physiographic interest b

1. Warren Upham, The Glacial Lake Agassiz, Mon. 2 1895.
2. Daniel E. Willard, The Story of the Prairies, Ranc
3. Thomas E. B. Pope, Devils Lake, North Dakota, U. Document No. 634, 1908.
4. First, Second, Third, Fourth, and Fifth Biennial Geol. Survey, University, North Dakota.
5. Survey of the Proposed Division of the Mouse Ri R. Atkinson.

gentle and inconspicuous slope, becoming somew
again near Sheldon and Milnor, as the south
proached, and again so conspicuous in South
ceive the well-known name of the *Coteau des Pi*
out the entire distance across North Dakota the
dering the Drift Prairie Plain on the east rise
above the Red River Valley floor, in some pl
abrupt, in others gentle, but always is it coi
country of low relief.

THE GREAT PLAINS

On the western border of the Drift Prairi
similar and even more abrupt escarpment of
known in this region at the *Coteau du Missou*
ment trends from northwest to southeast, passin
Minot, and Steele, and rises 600 to 700 feet. T
pies fully one-half of the state and is a charact
the Great Plains. Its irregular surface varies i
1,800 to 2,700 feet above sea level, the relief b
to the erosion of nearly horizontal beds of shale
position and hardness. Only in the eastern po
the broad hilly belt forming the terminal mora
North American ice sheet, known as the Altar
the surface form the result of ice action.

THE DRIFT PRAIRIE

The Drift Prairie Plain, lying between the
mentioned above, varies in width from about
north to 100 miles at the south and has a gen
from 1,500 to 1,800 feet above sea level. This pl
but gentle slope eastward from the *Coteau du*
Pembina escarpment and *Coteau des Prairies*
from the international boundary line to the So
This double slope determines the direction of th
ing the several main streams to take a gene
course. The topography of this plain is that o
type characteristic of all that portion of th
which lies within the limits of the latest ice inv
from gently undulating through rolling to
being due almost entirely to the original di
unmodified glacial drift upon a nearly level
shaly character of the underlying rocks is such
influence the surface topography to any mark
where occasional groups of low well-rounded hi
ridges rise above the plain, and these are so w
drift that only their form reveals their orig
Sullys Hill, and the Blue Hills to the south ai
Lake are all of this type, being mesa-like remn
once continuous formations now all but eroded

ION, NORTH DAKOTA.

T.T. Quirke
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THE MOUSE RIVER VALLEY

The Mouse River Valley is a glacial m
similar to that of the Red River Valley, the :
formerly covered by the waters of Lake S(
lies between 1,100 and 1,600 feet above sea le
River Plain, it also is drained northward th
portion of the "Loop" of the Mouse River. 1
low flat lake plain between the *Coteau du Mi*
ern outlier the Turtle Mountains, accentuates
these two features, formerly united, and shows
the relative amount of work performed in t
agents of erosion in preglacial time as compare
work done since the close of the glacial epoch.

THE DEVILS-STUMP LAKE 1

With the possible exception of the Turtle M
Mouse River Valley, the most striking physiog
the Drift Prairie Plain and one of the most in
portant of the state is Devils Lake. This la
Stump Lake lies just within the southern bo
interior drainage basin to which it gives its n
extends from the southern slopes of the Turtl
the Canadian boundary southward to a series c
lying between Devils and Stump lakes and the
The eastern and western boundary lines are
indistinct, but the theoretical area of the enti
is estimattd at about 3,500 square miles.[2] Th
slope throughout the basin southward to thes
fall is so slight, however, and the surface so i
drainage is but very imperfectly developed.
ponds abound, especially in the southern port
few and very shallow, rarely containing ru
cept in wet seasons. Formerly these coulees a
lakes connected by them emptied considerable
Lake through Mauvaise Coulee and by several
lees into both the eastern and western arms
Mauvaise Coulee was the most important dra
entire basin. Its headwaters were gathered l
national boundary line and in its course southw
Sweetwater chain of lakes by Lake Irvine 1
passed, and entered Mauvaise Bay of Devils La
permanent stream. Today no surface streams
Devils Lake or Stump Lake except very mi

1. E. J. Babcock, Water Resources of the Devils Lake F
Report, North Dakota Geological Survey, 1903, page 208.

2. E. F. Chandler, The Red River of the North, Q
versity, North Dakota, Vol. I, No. 3, April 1911, p. 248.

Fig. 1. Morainic topography south of Mission Bay, Devils La
veneered with recessional moraine in background, deep ir
foreground. Indian house on left. (Knudson.

Fig. 2. Morainic topography north of East Bay, Devils La
gentle swells and shallow pans. Smaller pan in foreground
larger one in rear is encrusted with alkali (Augu
Isolated kame in background.

animal has happened across leaving a distinct ·fringes of small trees, of which poplar is perh mon, are found in these moist depressions in such numbers as to add variety to the landsca this country of low relief an odd type of inv This is particularly true of the neighborhood Grove, between Creel Bay and Six Mile Bay nor

To another type of depression found occa prairie interest attaches out of proportion to significance. These are the "buffalo wallows, earth has been carried away as mud on the bo mals or has been stamped and pawed by thei and then blown away by the winds. In the cent sion is usually found a large boulder in the p may be seen the indirect cause of the depressi is generally well polished on its edges and proj the rubbing and scratching of the buffaloes of formerly in this region many herds of countles

The best illustration of the buffalo wallov the southeast corner of the West Bay of Stu farm owned by Mrs. Jennie Thatcher. This wa in diameter and three feet deep. A large rec seven and a half feet long by seven feet wide an feet above ground stood in the center. The highly polished corner gave indirect but unmi of the origin of the depression.

Occasional drift hills or groups of knobs than the rest are found capped with sand and their kame like origin.

The region is almost unmarked by draina few well-marked coulees, through which little today and which are very evidently channels of The only exception to this general absence o channels is to be found in the immediate vicinit River whose deeply eroded valley gives outl tributaries which are not now being pushed into the upland, owing to the short season in tain water and the hardy growth of grass found mer season.

The plain is typically prairie, yet in the i of Devils Lake is found a large portion of th timber of North Dakota. The woods are clos chiefly on the north and south sides near the r oak, elm, ash, and a large variety of other tre

the result of human agencies, such as drainage and tl of the soil, but in general the size, depth and perma lake depends on climate.

The Shore Line.—The remarkable length and ir the shore line of Devils Lake have already been note ent shore is almost everywhere covered with bould bles (Plate XVII) generally incrusted with a white posit, or consists of gravelly and sandy stretches down to the water's edge in series of belts (Plate or more rarely steps, from the ancient cliffs or beache and often far back from the present shore. The s slopes and beaches, each marked by its characteristi and the heavy forest growth which prevails upo levels and the upland are very striking. (Plate XV,

Floor of the Lake.—The form and character of the lake was studied in detail by the Bureau of Fishe when a hydrographic survey of the Main Bay was m servations taken on all other portions. In his report vey Thomas E. B. Pope says:

"The floor of the lake is practically level, rising f of 25 feet to the shallow portions near the shores or f bars and stony reefs at the mouths of bays. In gener est area is that of the southern side under the lee of t ridges of Sullys Hill and Fort Totten, while the en section beyond LaRose Ferry (Minnewaukon Bay) feet deep, with underlying soft black mud supportin ance of weeds and inaccessible to all but the lightest d

The sandy and gravelly beaches of the steeper tions, the muddy character of the main floor and of a bays and rapidly shoaling shores, together with the a water weeds now growing in shallow bays, was attest observations in the field. Owing to lack of inlet an sence of cliff cutting by the waves, filling upon the lake is extremely slow and unimportant, and only in th low bays is there a noticeable accumulation of veget Over the broad head of Creel Bay, dry since 1889, inches of filling is found overlying the drift floor.

Composition of the Waters of Devils Lake.—Th Devils Lake may be termed alkaline and brackish show a salinity of about one per cent, of which mag sodium salts constitute a considerable portion. Ana U. S. Bureau of Chemistry shows the following compo

Minnewaukan Bay.—This large bay, scarcely sec
Main Bay in size, formerly extended from the villag
waukan 11 miles eastward to LaRose Ferry at the so
of Grahams Island. At the time of the Bureau of Fis
vey in 1907 no point was found more than eight fee
and it was in most places much less, while the soft bla
the flat bottom supported such an abundance of weeds
it inaccessible for all but the lightest draft boats.
years 1910 and 1911 only skiffs and a single launch
inches of water have been able to pass the narrows
Ferry, and the launch succeeded only in early spring. T
half of the bay is almost dried up and covered with
weeds. Occasional ponds and a small channel extendin
mouth of Mauvaise Bay, are the only remnants of th
broad expanse of water.

From Minnewaukan Bay only one secondary bay
ance leads off. This is Mauvaise Bay, or Pelican L
opens at the northwest end of Grahams Island and ext
and northwest about six miles. Into the head of th
emptied the only known inlet of Devils Lake, Mauva
Two or three small detatched bodies of water, connect
summer by a narrow, shallow channel, is all that rem
once important stream.

Main Bay.—The Main Bay is today the only sec
portance in Devils Lake. It extends from the LaRo
the Narrows, five miles south of Devils Lake City, a
the Great Northern Railway Bridge and a causeway
public highway have been built, entirely cutting o
nection with the eastern portion of the lake. This ba
fore, about eight miles long and at its widest point
mouth of Creel Bay to Sullys Hill, four and a half mil
According to the Bureau of Fisheries survey it embra
area of 34.5 miles in 1907. Here was found the maxi
of 35 feet in 1883, which by 1907 had been reduced to
this to 23 in 1911. The deepest area extends from th
the bay to the lee of the Sullys Hill range. The botto
level floor of soft black mud gradually ascending to s
elly, or even bouldery shores.

Several important bays open into the Main Ba
these being Creel Bay in the middle of the north sho
Bay in the northwest end, Mission Bay and Black Ti
the southeast, and the broad open Fort Totten Bay op
Bay on the middle south shore.

Creel Bay.—Most important of all the smaller
lake is Creel Bay. At the time of the original surv

formed Devils and Stump lakes. While the ba
but ten feet being reported in 1907, the direction a
the straight, smooth, and steeply sloping sides
strongly than in any other bay the scooping action
ice, after the manner of the formation of the well
of Finger Lakes of New York, including Cayug
others. The northern end shoals less rapidly than
the water has retreated not to exceed a mile. Other
lines differ but slightly from those shown on the
(Plate XI.) A causeway with but one small w
crosses the bay from east to west about one-third of
the northern end anticipating at this part of the b
formation of a bay head bar, the two spits at eithe
were well developed before the causeway was con

Mission Bay.—This very irregular bay exte
southeast corner of the Main Bay and in 1883 w
into Mission Bay and Little Mission Bay. The lo
irregular portion extending in a southeasterly dire
cut off by bars, much of it has dried up, and the p
ing is known as Mission Lake. Little Mission Bay
reduced by bay head bars to what is now terme
and Little Mission Lake. (Plate XX, Fig. 2) The
southwesterly, has a length of less than a mile wit
less than one-half mile. In 1907 the deepest water r
bay was eleven feet, with but five and one-half feet
over the bar across the mouth. The bottom is cov
black mud into which an oar can be sunk at least t
the shoal south end the water weeds grow in such
make progress with a light launch very difficult
peatedly entangle the propeller. The shores are u
and gravelly.

Fort Totten Bay.—This historically importa
south side of the Main Bay is so broad mouthed as
by many as but a portion of the Main Bay, yet o
is it that it is well deserving of emphasis. It is abo
and a mile across. The crest of Sullys Hill, the h
the region, commands the entrance on the east s
base a boulder-covered point juts out into the ga
sive shale beaches on the western side of the ba
the discovery there of outcropping ledges of Pi
only known bedrock exposure in the lake, which h
the location of this side of the mouth. (Plate XVI
bay is undoubtedly deeper than most of the bays,
are wanting.

The beautiful little spring-fed body of water l
Sweetwater Lake, which lies in behind the hills t

by Mr. Marshall Brannon of the Biological Survey but a depth of thirty-nine feet. The trend and character of this bay suggests considerable scoopin in central and north portions. Extensive springs i end of this bay supply a considerable amount of ve to the lake. Here also are the remains of an anci stumps of which, until recently submerged, have g to the lake. (Plate XIX.)

Harrisburg Bay extends in a general easterly near the southern end of Eastern Bay and while of a mile in width near the mouth narrows to a tance of three miles.

Swan Lake.—Swan Lake is a small detache Stump Lake lying north of the extereme northern lake and connected by a coulee with the larger lake end as well as into the extreme eastern end of H several coulees, now generally dry, formerly poure

The Sweetwater Chain of Lakes.—Lying about miles to the north of Devils Lake and having a ge parallel to it is a chain of lakes sometimes known water group from the largest and best known of th series of lakes owe their origin to glacial agencies constructional type, since they lie in the flat lowla ridge of hills known as the Itasca moraine, wh age down the natural slopes from the north is ch depressions in many of the moraines filled with wa of a broad, shallow, irregular type characteristic gin and location.

Lying as they do in this position, they form basin with a down slope to Devils and Stump lak the lower southern portion of the same natural formerly received the drainage, both surface a from a large area, but are today without appare in wet seasons, and are subject to great fluctu years. Formerly these lakes were all connected the following order from east to west:

Sweetwater Lake, Cavanaugh Lake, Dry Lake Lac aux Morts, Lake Irvine, and thence through M with Devils Lake, into which they poured a consid water. Not only is there now no outflow into De the connections between the lakes is rarely made. lakes, notably Dry Lake, are dry beds or grassy of the time.

The chief interest in Sheyenne River lies, the present stream but in the history of that doubtless much larger than the present stream, drainage from the great ice sheet when it stoo along the great morainal divide south of Devi outlet of glacial Lake Souris and the earlier an and Stump lakes.

It was during this period of the greater Sh great valley, far too large for the work of the sm flows through it today, was carved. That th deep into the original bed rock underneath the d from the plentiful exposures of the Pierre shale bluffs of the old valley are undercut by the pre places where the valley is sunk to the depth of 15 low the upland one-half to three-fourths of the dark gray shale. Terraces in the train of grav the valley during the retreat of the ice are rema veloped.

THE BED ROCK

In the region about Devils and Stump lakes is so thick and so uniformly distributed that fe the underlying strata are found. There is, ther portunity for the study of the bed rock. The crops occur in widely separated localities in th walls, the margins of the lake basins, and in From these and from the samples and logs of t we may, however, learn much of the underlying s when this data is correlated with that of the mor posures farther east, where the larger rivers hav leys through the Pembina escarpment as they flo Red River plain.[1]

CRETACEOUS SYSTEM

THE PIERRE SHALE

All evidences point to the fact that but one mediately underlies the drift of this entire region of the whole of the Drift Prairie plain. This form where readily recognized as the Pierre shale, the rived from Fort Pierre, South Dakota, where it oc acteristic outcrop and is exposed over a large area

Shale is composed of particles of mud pressed together into a compact mass. Such rock in a w indicates that the mud from which it was derived in large bodies of water, the thin and very unifor

1. For a brief, but comprehensive, account of the gener state, see A. G. Leonard, The Geological Formations of No Biennial Report, N. Dak. Geol. Survey, 1904, pp. 146-177.

The 1,403 feet of dark gray shale beneath the drift and above the Dakota sandstone was not differentiated by the driller but it undoubtedly included the Pierre, Niobrara, and Benton shales. In outcrops in the Pembina escarpment near Walhalla both the Niobrara and the Benton are well shown. The Niobrara is somewhat lighter in color than either of the others and quite calcareous. The Benton is darker, almost a jet black in large part, and not infrequently contains pyrite nodules and gypsum crystals.

The lowest member of this section is the Dakota sandstone, penetrated at a depth of 1,431 feet and which at 1,470 feet, just at sea level, yielded a strong flow of brackish water carrying much fine white sand in suspension. No outcrops of this formation are known within the state, but since it is the chief artesian water horizon it has been reached by the drill many times and is well known from drill samples. This important water bearing sandstone probably underlies the entire state except a portion of the Red River Valley, where granite is reached at comparatively shallow depths. Westward it extends to the Black Hills and the foothills of the Rocky Mountains where it rises to the surface and gathers the waters which gush forth so plentifully in the artesian wells of the eastern part of the Dakotas.

All of the formations shown in this well section, which extends 41 feet below sea level, belong to the Cretaceous system, so called from the large amount of chalk contained in its rocks in some portions of the world, notably southern England and Texas. Something of its characteristics is shown at Concrete, where an attempt has been made to utilize the Niobrara beds in the manufacture of cement.

GEOLOGIC HISTORY.[1]

During the time in which these rocks were being deposited a great inland sea stretched from the Gulf of Mexico northward to the Arctic Ocean, separating the North American continent into two parts and covering a large portion of the great interior plain, including this region, with deep water. On this sea floor were deposited the same kind of sea muds that are being deposited in the moderately deep off-shore seas of today.

In the western portion of the state are found a few outcrops of a sandstone overlying the Pierre shale known as the Fox Hills sandstone. This is the youngest formation laid down by the great inland sea which covered this region during Cretaceous times. No occurrence of the Fox Hills or any younger formations is known in the Devils Lake region. Whether these forma-

1. For a more complete account see A. G. Leonard, The Geological History of North Dakota, Fifth Biennial Report, N. D. Geol. Survey, 1908, pp. 229-243.

greater the proportion of foreign matter. In the case of the boulders, all are foreign not only to this locality but to the state as well.

The intimate intermingling of the various materials is such that it may be easily seen that the drift is not the result of the disintegration and decay of the underlying rock in situ, and that it has in fact no direct relationship to the bed rock on which it rests. (Fig. 3). This fact is emphasized by a study of the mantle

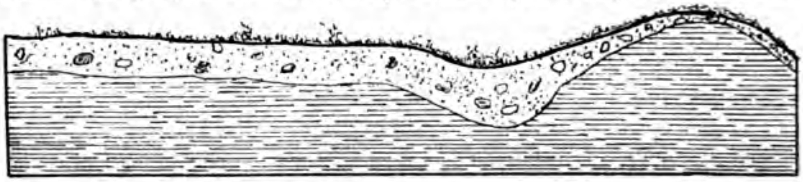

Fig. 3. Diagram showing the relation of drift to bedrock in a glaciated region.

rock and the bed rock where it outcrops on the sides of the Sheyenne River valley and the few other places noted in the preceding pages. If this mantle rock were formed in place it would grade by almost imperceptible degrees from the surface soil downward through the subsoil, and the more and more completely disintegrated rock into unaltered bed rock, and the residual soil thus formed would be free from foreign matter except that of an organic nature. (Fig. 4.) Such gradation from bed rock into

Fig. 4. Diagram showing relation of residence soil to bed rock in an unglaciated region.

residual soil would be the combined result of the work of weather, ground water, the roots of plants and burrowing animals, acting upon the country rock and causing its decay. The absence of this gradual transition and the presence of abundant foreign matter leads us to infer that the mantle rock is transported material. The occurrence of this material over a large portion of the state. as well as over an immense area in the northeastern part of North America suggests uniform conditions over widespread areas. The early belief that the agent of the transportation and deposition was water and that the material had drifted into its present position gave rise to the name which it still bears—the drift. This opinion was sustained to a degree by the occasional evidence of assortment and stratification of these materials in more or less

EXTENT OF THE GLACIATION

The glaciation must have been as extensive as the drift is widespread. Glacial ice is therefore known to have covered at its maximum development an area in North America approximating 4,000,000 square miles, or about ten times that of the present ice-field of Greenland, and fully the size of the ice sheet now capping the Antarctic region. This area includes practically all of Canada and in general that portion of the United States north of New York Bay and the Ohio River and east of the Missouri River.

Within this great area once covered by ice there is an area of several thousand square miles in southwestern Wisconsin overlapping into northeastern Iowa and southeastern Minnesota where there is no drift. This region, for some reason, remained uncovered by ice, though evidences of glaciation are found in the region entirely surrounding it.

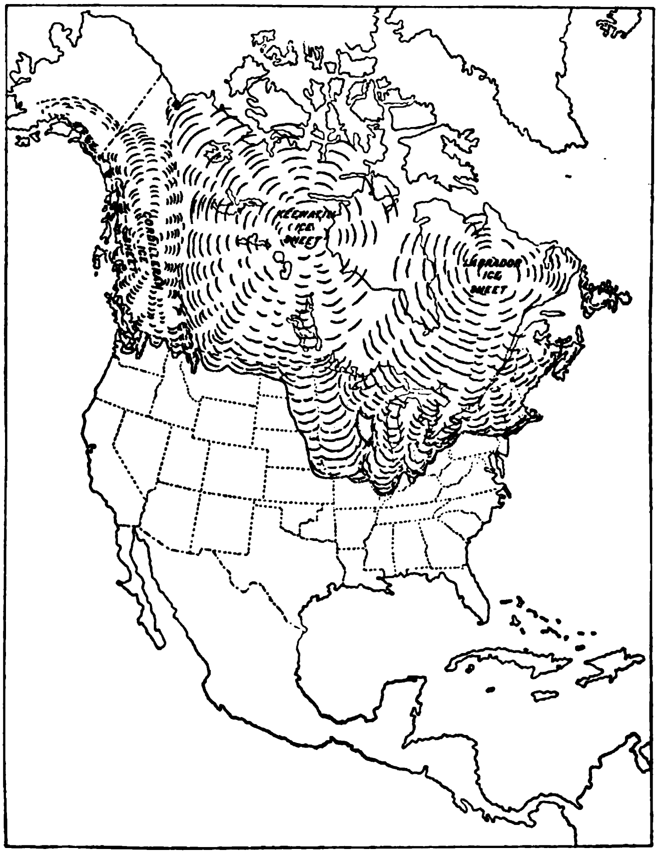

Fig. 5. Map of North America showing maximum extension of glaciation and centers of accumulation. (U. S. Geol. Survey.)

Fig. 5 shows the limits of the ice advan(It will be seen that this state was invaded by lobes into which the southern edge of the] sheet was divided. These are known as the I Minnesota lobe, and their line of contact was hills known as "The Ridge," which lies bet Edinburg. This ridge is formed of material line of slight movement between these two therefore a medial moraine. The region und(the west of this moraine and north and east (raine and is therefore in the area covered by the ice sheet. It is known that this state wa vaded by an ice sheet and many of the surf region are the result of the latest of the ice i the Wisconsin epoch.

CAUSE OF THE GLACIAL PERIO

It must have been an extraordinary cha led to the development of the great ice field (northern North America. Why such an enor developed so far from either pole has never explained, but it was probably due to some logic or geographic change. That this char produced widespread climatic effects is seen a similar sheet with its center on the Scan covered all of northwestern Europe and most while another independent cap covered the Greenland, lying between these two continent more completely than now by an ice cap. Th tor in the development of these great ice shee a reduction of temperature, yet the fact tl beria were free from ice indicates that not on but an abundance of snow was an essential c

The hypothesis which at present seems b changes of climate refers it to a change in the atmosphere, probably to a lessening of the a oxide gas.[1]

FORMATION OF THE ICE SHEE

With the change of climate more snow f(certain portions of Canada than melted and the ensuing summer. The resulting accumu formed a snow field which grew thicker w winter. As the climatic change grew more field was extended, and "This extension of t promoted a lowering of the temperature of

1. Chamberlin and Salisbury, Geology, Vol. III, pp

erosion of the preglacial surface by the ice, and (2) through the deposition of the drift.

The relatively thin edge of the ice crept very slowly over the surface of the ground. It probably pushed up a little of the soil in front of it, but the water-saturated soil was undoubtedly frozen as the ice advanced over it. The solid mass of soil and partly decayed rock was broken, crushed, and frozen into the ice, became in effect a part of the mass, and was carried along with it. Much of this material was worked up into the lower part of the ice and the continental glacier thus holding fast great quantities of clay, sand, pebbles, and coarse stony material in its powerful grasp, bore down with tremendous power and weight upon the bed rock and residual waste beneath, tore up and carried along all the loose fragments within the zone of surface decay and disintegration, plucked angular blocks of stone and ground, scraped and rasped the bedrock below until the surface of the latter was reduced in some places many feet below the former surface.

In the rougher country crags were removed and the higher elevations scoured and rounded off, and valleys trending in the direction of the ice movement were scoured out and deepened as in the case of the so-called "finger lakes" of New York.

Owing to the soft, yielding character and the horizontal attitude of the bedrock in the Devils-Stump lake region, the erosive work of the ice is not marked. The surface was probably not greatly reduced, but was stripped of the loose soils and disintegrated rock and then generally overridden, the ice being unable to get foothold on the shales. The ancient mesas and buttes remaining above the old Tertiary peneplain were rounded and reduced, but otherwise retained their general form as seen in Big Butte, Sullys Hill, and Blue Mountains. Evidence of valley deepening may be seen in the bays of the lakes having a north and south trend, notably East Bay of Stump Lake, Six Mile Bay and perhaps the lower end of Creel Bay in Devils Lake, but in none is the effect very striking.

On the whole the major topographic forms were not, however, greatly modified by erosion; they were simply reduced and rounded by the ice. The minor topographic forms were, however, highly modified and frequently obliterated by the mantle of debris spread over them. Valleys were blocked, partly filled, or completely buried with drift, those lying across the line of glacial movement being most affected. The smaller hills were changed in contour, and often completely covered.

In the prairie regions, where the bed rock was soft and yielding and the topographic relief mild in character, the effects of erosion and deposition together almost obscured all earlier topographic forms, leaving a new topography composed chiefly of the irregularities of the drift itself. Such was the case in the Devils Lake region.

Abandoned beaches on Chautauqua road, east shore Creel B
stands on the A beach midway between the A and

[redacted]

GLACIAL LAKE MINNEWAUKAN

So much larger were the glacial lakes than the present lakes, and so different in form, that it seems advisable, in order to avoid confusion, to give them distinct names. To the glacial lake of which Devils Lake is the remnant is restored, therefore, the original Sioux Indian name for this body of water, Minnewaukan, meaning "spirit water," a name which has suffered much in translation, due to the white man's conception that all spirits are of the evil one. The original name has fortunately been retained for the town formerly on the shore of the western bay but now unfortunately some distance inland. The glacial ancestor of Stump Lake will similary be called Wamduska, the Indian name for this beautiful body of water. This term means serpent in the Sioux language and is thought to have been given on account of the fancied resemblance of the form of the lake to that of a great serpent crawling westward. This name is still retained for the township in which the larger portion of the lake is found and was applied to the now abandoned townsite on its northern shore.

THE OUTLET OF LAKE MINNEWAUKAN

Lake Minnewaukan, unlike its smaller successor, had at least one well defined outlet, that by Jerusalem eastward to Lake Wamduska and thence past Tolna to the Sheyenne. Undoubtedly the several temporary marginal lakes formed between the ice front and the irregular moraine which forms the divide between the basin of the lakes and that of the Sheyenne River each had outlet over the lowest col of the morainal southern rim into one of the great glacial spillways. The crest of the divide in each of the four great spillways before mentiond is so reduced and so inconspicuous as to make it highly probable that each was used for a time as an outlet for a considerable body of ponded water.

Seven Mile Coulee which leads almost directly south from Fort Totten Bay through Little Sweetwater Lake, was evidently thus occupied, but not long. The Crow Hills Coulee to the west of Crow Hills, leading from the southeastern corner of Minnewaukan Bay was probably used longer but with the elevation[1] of its crest at 65 feet above the present lake level and thirty-three feet above the highest well-marked shore line this outlet was short lived. Others are thought to lead from Mission Bay or Black Tigers Bay, but they are not well defined. These spillways cannot, however, be considered as outlets of the modern Devils Lake since all are distinctly higher than the outlet eastward past Jerusalem.

1. T. R. Atkinson, Report on the Survey of the Proposed Diversion of Mouse River to Devils Lake, 1912, (profile).

Fig. 1. Natural sea wall, ice built, on north shore "Rock
(Henderson.)

Fig. 2. Chautauqua Point, Creel Bay, Devils Lake, looking
vegetation and logs in middle ground (You

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GLACIAL DRAINAGE RELATIONS

The size of these outlets just described appears strikingly out of proportion to the lakes drained, even when the large size of the earlier lakes is considered. The key to the solution of this problem is found in the almost equally large inlet into the northwestern end of Devils Lake known as Mauvaise Coulee. The relations of Lake Agassiz and Lake Souris to the glacial drainage of the western margin of the continental ice sheet form one of the most interesting chapters in the glacial history of North America. That portion involving Devils Lake region will be briefly outlined.[1]

Lake Souris had outlet southward, as did all of the other marginal glacial lakes, first from a point near Velva through a well marked channel west of Dogden Butte, in which lie Strawberry, Long and Crooked lakes, to the Missouri River. This channel is well defined and was probably occupied for some time

Later a lower outlet was uncovered eastward by way of Big Coulee, one of the head streams of the Sheyenne, and Girard and Buffalo lakes to the James River, the lower valley of the Sheyenne being still buried beneath the ice. When, however, the edge of the ice had retreated so that it stood on the high hills south of Devils Lake and poured a flood of waters through the spillways before described into the present Sheyenne Valley, thereby rapidly cutting and deepening it, the Lake Souris waters were diverted from the James River and entered Lake Agassiz through the Sheyenne River.

Still later, when the ice had retreated sufficiently to uncover the Turtle Mountains, and the great lowlands west and north were covered by the waters of Lake Souris, a still lower outlet was found across the international boundary and east of the Turtle Mountains by way of Mauvaise Coulee into Lake Minnewaukan and thence through the Jerusalem outlet, Lake Wamduska, Big Stony Coulee and Sheyenne River into Lake Agassiz.

We can little comprehend the vast flood of water which passed this way from the southern and western front of the great ice sheet. From the far northwest, including even the basin of the great Assiniboine River and glacial Lake Saskatchewan, 300 miles to the northward, came the flood of glacial waters through this great chain of lakes and their connecting rivers, which must have somewhat resembled straits, to the Mississippi River and Gulf of Mexico. This was flood time in the Devils-Stump Lake region, when Lakes Minnewaukan and Wamduska stood at their highest level.

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1. Warren Upham, Glacial Lake Agassiz, Mon. 25, U. S. Geol. Survey.

Fig. 1. Rock Pile Island looking north from spit building shore of lake (Henderson).

Fig. 2. Eastern shore of Rock Pile Island, lool

and embayed character of the lake is such that formed from islands and points just as the pr today, spits from opposite points united to foı developed into barrier beaches, changing the ba lakes. This work was frequently anticipated by bayhead bars cutting off the heads of the bays ε into small lakes. This latter process was in s times repeated before the mouths of the bays forming series of small lakes or lagoons in su dessication.

The A Beach.—The two distinct levels at of Lake Minnewaukan stood for a considerab are indicated by well defined shore lines. The marked by strong cliffs where the relief is st Fig. 1) and where the form of the lake and th storm winds are such as to render the wave atta In places of slight relief and on low shelving sh of sand and gravel and even of large boulders a ter due undoubtedly to the work of shore ice.

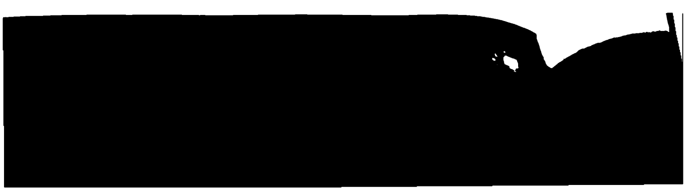
The position of the highest beach has been naissance on the north side of Devils Lake betw of Six Mile Bay near Grand Harbor and Indian southeast end of the lake, also through Jeru about Stump Lake. Evidence of ice shove in the stock yards on the Great Northen Railway Devils Lake city seems to offer conclusive p still formed the north wall of at least a portio was active during the A Stage.

The water of the first stage, therefore, s foot level outlet, and being held there for a c of time formed the very distinct A series of This shore line is well developed on the west s grounds as a cliff and in the nursery just e Devils Lake is marked by a strong beach. I tion from a low cliff to a good beach which f in a spit is readily seen and interpreted from of an eastbound train as the track parallels th south for a short distance.

In some places the evidences of this sho obliterated by the retreat of the cliffs of the ı stage. This is strikingly illustrated along the Main Bay adjoining the parade ground of the tion. Here the strong wave work during the the B cliff back until it obliterated all trace leaving the most conspicuous cliff to be found lake shore.

Fig. 1. Land-tied "Rocky Island," west side Fort Totten B
shale beach in foreground. (Henderson

Fig. 2. Old Tolna outlet of Stump Lake, looking east from
Big Stony Coulee and Stump Lake drair



The only additional evidence as to the t stage is to be found in the amount of wave cliffs during this stage. This seems, on the w that during the B stage, and it must be r waters of this stage were less hampered by t lated on the beach than later stages increa may be learned from deposits save negative low kettles in the drift beneath the A bea were unfilled during this period.

The B Stage.—The second stage of La known as the B stage. During this time th stood at an elevation of 1,453.5 feet, 28.5 fe lake level and 6.5 feet below that of the A s by way of Jerusalem into Lake Wamduska, the waters of the two lakes into Sheyenn Such relations indicate that the evaporation the combined lakes exceeeded the inflow. Th inflow was due first to the recession of the in a diversion of the glacial drainage and a climate.

Below the B stage the water was neve level by outlet or otherwise a sufficient lengt cliffs, though well-marked beaches occur i indications point to the fact that all the b stage are very recent as compared with th stages. With the falling of the waters bel coulee at Jerusalem the lake ceased to have sumed a form and character similar to that The history of the glacial Lake Minnewauk Devils Lake.

The B Beaches.—Undoubtedly the Jerus ized and the work resumed several times in t the lake, but the overflow checked the rise of produced a maximum stage beyond which t rose sufficiently to flow into Sheyenne Riv the A stage. The gradual fall of the water levels and possible later rises is indicated by not by characteristic cliffs, between those those of the B stage. These belong properly are occasionally noted as B+ beaches wherev

The inflow from the Harrisburg sloughs Stump Lake has been small compared with t by Mauvaise Coulee, since the outlet from D Lake was maintained long after the outlet of The B series of cliffs and beaches very sim

of the geologic relations shows also that the water within the drift is southward througho and is therefore into the lakes, while seepag to the southward is barred by massive shale l through the drift filling the preglacial valle strong tendency to seepage and from the f doubtedly a till-filled valley it would not be

The B stage, during which time Devils Stump Lake did not, may be considered in tl ition stage. From the standpoint of drain longs to the recent or interior basin stage, bu these lakes were probably maintained at the into the Sheyenne only by glacial drainag when these waters were diverted by the Pe struction was not climatic.

So long as a lake has a constant outlet th sweet, but interrupted outflow gives rise to and long continued absence of outlet results i of salts left behind by the evaporation of a lar as to form a strong brine.

Connection between the several lakes ly portion of this interior drainage basin has intermittent as to result in several gradua water and brackish; the extremes are probal geographic ends of the formerly connectec Sweetwater Lake with its most recent im Stump Lake, the one evidently longer witho

The ephemeral character of the shallow drainage system is also well illustrated in th reappearance of some of the lesser lakes of t Dry Lake. The most striking feature of th is the evidence of gradual reduction to be se lakes. This is remarkably well shown in th of lakes.

"A careful study of the shore line and deposits about Lake Irvine and to the s plainly that the small lakes north of Devils much larger at some time in their history. that Lake Irvine, at no very remote period. mile to three miles farther east, and stretchi widened out irregularly three or four mil southeast. At this time Lac aux Morts, T Lake were probably connected and formed which may have been continuous with Ca

Fig. 1. Mission Lake, Mission Bay and Devils Lake shov "points," two stages in transition of bay and lak

Fig. 2. Court Lake, a freshwater lake, showing final st timbered beach in background is same as that in foregro

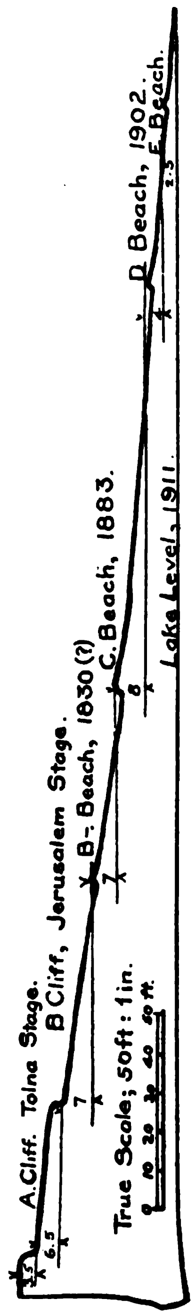


Fig. 8. Section of shore of Devils Lake midway between steamer landing and Chautauqua Point, showing characteristic cliffs and beaches.

Traditions[1] connected with the old trading post of Augustus Roche, established about 1819 on the extreme northeastern point of the timebered upland which bears his name, indicates that this was an island at that time, but that the water stood at a level not lower than 1,466, nor higher than 1,453 feet. The field evidence favors the former.

The earliest historical statement of level of Devils Lake[2] places the elevation at 1,446, about 1830. This is 21 feet above the low stage in 1911. If this is correct, it undoubtedly fixes the date of the B— beach as the highest level attained since the outlet ceased. This line is about seven feet[3] below the outlet level and limits the hard wood timber of the groves of Roche Island, only smaller scattering trees, chiefly box elder and willow, being found below that level.

Beginning in 1867, occasional well authenticated records of levels are found. That the water stood at the B— stage as late as 1867 is corroborated also by traditions which show that Roche "Island" and Grahams "Island" were still islands and that water to a depth of three or more feet was found at the ford across the narrow strait seperating Roche Island from the mainland south of Devils Lake city.

In June, 1901, a guage was established by the United States Geological Survey on the piles supporting the pier at the Chautauqua steamer landing. The gauge zero is 1,416.2 feet above sea level and is 22.90 below the bench mark established by the same survey about 130 feet in the rear in the yard of Capt. E. E. Heerman, owner of the pier. This gauge was read at intervals for several years by Capt. Heerman and is now read by the staff of the State Biological Survey, the lakeside station of which is located on the adjacent lot.

A list of observed gauge heights of the water level, together with a few of the previous records reduced to gauge readings, is tabulated below:

1. Traditions among both the Indians and the French agree that the Sioux crossed the Narrows in buffalo skin boats and skirted the woods, approached the post from the west, killed one of the traders on the beach, and drove off the others. The beach indicated on the west must be between B and B— inclusive.

2. Warren Upham, Glacial Lake Agassiz, Mon. 25, U. S. Geol. Survey, 1894, p. 595, (Authority not cited).

3. Upham's statement (ibid) that the outlet level was reached at this stage may be explained in part by his belief that tilting had occurred between Devils Lake city and the Jerusalem outlet—a theory for which no corroborative evidence could be obtained by the author. Careful leveling to the highest shore line at Devils Lake, Chautauqua, and at the Tolna outlet reveal an elevation of 1,460 feet at each point.

GAUGE HEIGHTS IN FEET, OF DEVILS LAKE

Date	Gauge Height
1867	26.75
1879	22.90
1880	18. [illegible]
1883	22.88
1887—	
Aug. 8	15.4
1889	13.8
1890—	
August	13.0
1901—	
June 7	12.15
June 8	12.4
June 23	12.35
June 27	12.25
August 17	12.05
September 14	11.9
September 19	11.65
September 26	12.15
October 8	12.1
October 21	12.05
1902—	
April 25	13.55
April 30	13.6
May 5	13.8
May 7	13.85
May 24	13.95
June 5	14.0
June 10	13.95
June 13	14.1
June 22	14.0
June 27	13.95
July 15	13.7
August 7	13.5
August 23	13.7
September 13	13.2
September 28	13.2
October 12	13.1
October 22	13.05
November 15	13.0
1903—	
May 29	13.1
June 5	13.1
June 13	13.1
June 17	12.9
June 26	12.8
July 6	12.6
July 10	12.55
July 19	12.4
July 25	12.3
August 15	12.2
August 25	12.1
August 29	12.2
September 10	12.1
October 27	11.9
November 15	11.75

D
1904—
April
April
May 1
May 5
May
May 1
June
June
July
Augus
Septen
Octobe
Octobe
Noven
1905—
July 1
July 1
Noven
1906—
April
May 6
June
June
July
Augus
Septe
Octob
Noven
1907—
May
June
July
July
July
Augus
Augus
Augus
Nover
1908—
April
June
July
July
Augus
Augus
Augus
Augus
Nover
1909—
May
May
May
June
July 1

water, a period of comparative if not complete d seems to have marked an epoch of relative aridi Such an epoch may have coincided with the yet tions of the Great Basin, which appear to have Pyramid, Winnemucca and other lakes of Nev ending about 300 years ago.[1] The minimum len of dessication in this region is suggested by the these stumps at Stump Lake measure twenty to t in diameter and show 120 to 130 annular rings.

Thus we see that Devils and Stump lakes ar iodic fluctuations in response to variations in w to rainfall and also to certain greater fluctuatio considered as climatic in their nature.

Studies in the climate of the earth have sho rather definite changes characteristic of the se climate and particularly evident in rainfall, in a earth. Theses changes occur in fairly well n 11 and 35 years, and undoubtedly of longer p not so evident. The cyclic character of rainfall h both directly by measurement of rainfall and fo by the effect on lakes and streams.

The most marked effects upon drainage o basin regions, as in the case of Devils Lake, rises during periods of heavier rainfall until e the increased surface balances the supply, oth maining the same, and the amount of rise woul increase in rainfall. The ratio would not be di ing, however, owing to the increase of area of th in flat basins, with increase in height of surface.

Besides these fluctuations there appears to Stump Lake region a progressive change since t when a very wet climate prevailed toward a dry affects all lakes and all regions and may be sa in character. Such changes are most faithfully r ior drainage basins, and it is hoped that furth region may throw more light on the character an change.

One other factor remains to be considere of Devils Lake. The rapidity of dessication ment of the region in 1883 and 1884 has been to demand explanation other than climatic or m lowering of the lake level seems to be due to crease in runoff and a lowering of the ground w

1. Russell, Geological History of Lake Lahontan, M Survey, pp. 223-237, 252; also G. K. Gilbert, Lake Bonnevill Survey, p. 258.

conditions suggest a decrease in rainfall, but extended observations of the United States Weather Bureau stations disprove this. This condition is one which has been common throughout the prairie states of the Middle West and is best accounted for by the extensive cultivation of the soil. The prairies were formerly covered by a thick, tough, almost impenetrable sod which favored runoff and prevented rapid evaporation from the soil. The conversion of this sod cover into cultivated fields, the surface of which is kept loose and porous by the plow, disc and harrow, greatly interferes with the runoff and absorption is increased. This would tend to raise the ground water level and thus equalize the loss of lake level by decrease in inflow, were it not for the fact that the cultivation of the soil, and particularly the planting of such crops as corn and wheat, causes a very great loss of soil moisture by evaporation both directly and through the plant, which moisture is replaced by capillarity from below, thus reducing the ground water table and consequently lowering the level of all permanent lakes and streams and causing many to become intermittent or temporary and some to disappear entirely. It also results in the disappearance of springs and the failure of shallow wells. These conditions have all been reported in the Devils Lake region, but are common throughout the prairie plains of the Middle West. In Iowa, for instance, the three generations of wells may frequently be found on a single farm: the shallow dug well, the deeper bored well, and the tubular well drilled into rock. Increased demand for water with increase in stock only partially accounts for the necessity of the deeper well. The final cause must be found. Subsidence of the water table and cultivation of the prairie offers the best explanation for this.

THE FUTURE OF DEVILS LAKE

The future of Devils Lake may only be read from the past. The progressive decrease in lake level since glacial times may be regarded as due to geologic causes and may be expected to continue indefinitely. Half of the morainal lakes of the United States have been converted into marshes, meadows, and rich farming lands and only the peaty and marly character of the soil remains to show where the lakes have been. This is especially true of those portions of the Middle West unaffected by the latest ice sheet. Such changes involve, however, geologic periods of time. They cannot be measured in terms of human life and are so slow in operation as to be of scientific interest only.

Fluctuations in response to variations in rainfall may be repeated in the future as in the past and those of a cyclic nature undoubtedly will be repeated. Periods of rise will follow periods of fall. It is not improbable that these may bring variations of